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PROBLEMS AND OPPORTUNITIES IN MANAGEMENT OF COMBUSTIBLE SOLID WASTES

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PROBLEMS AND OPPORTUNITIES IN MANAGEMENT OF COMBUSTIBLE SOLID WASTES

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This study was conducted in an effort to consider not only the cost and immediate environmental impact of waste management, but also the extent to which material or energy can be recovered from waste, the markets for such recovered resources, and the use of federal procurement and other incentives and disincentives to encourage resource recovery. The amounts of combustible solid wastes presently generated by agriculture, industry, commercial and service activity, and households are described and future waste flows from these sectors are projected. It critically reviews technologies that utilize or dispose these wastes, identifying the more promising ones. Finally, it examines governmental strategies to promote resource recovery or improved disposal, and recommends a preferred strategy for accomplishing these ends.

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FOREWORD

Man and his environment must be protected from the adverse effects of pesticides, radiation, noise and other forms of pollution, and the unwise management of solid waste. Efforts to protect the environment require a focus that recognizes the interplay between the components of our physical environment--air, water, and land. The National Environmental Research Centers provide this multidisciplinary focus through programs engaged in

- studies on the effects of environmental contaminants on man and the biosphere, and
- a search for ways to prevent contamination and to recycle valuable resources.

In an attempt to solve the problems involved in solid waste disposal, this study was conducted to investigate the extent to which material or energy can be recovered from waste, the markets for such recovered resources, and the use of federal procurement and other incentives and disincentives to encourage resource recovery. It should be of particular interest to those involved in solid waste management.

A. W. Breidenbach, Ph.D.
Director
National Environmental
Research Center, Cincinnati

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PREFACE

This report describes the amounts of combustible solid wastes presently generated by agriculture, industry, commercial and service activity, and households and projects future waste flows from these sectors. It reviews, critically, technologies for utilizing or disposing of these wastes and identifies the more promising ones. Finally, it examines governmental strategies to promote resource recovery or improved disposal, and recommends a preferred strategy for accomplishing these ends. It was prepared by International Research and Technology Corporation pursuant to Contract Number 68-03-0060 with the National Environmental Research Center of the U.S. Environmental Protection Agency. The factual statements, conclusions, and other information contained in this report do not necessarily reflect the views of the Environmental Protection Agency.

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I. INTRODUCTION

The Resource Recovery Act of 1970 amended Section 205 of the Solid Waste Recovery Act to require the Environmental Protection Agency (EPA), in carrying out its responsibilities relative to solid waste management, to consider not only the cost and immediate environmental impact of waste management, but also the extent to which material or energy could be recovered from waste, the markets for such recovered resources, and the use of federal procurement and other incentives and disincentives to encourage resource recovery. This study is a part of the work undertaken by EPA to carry out the Congressional mandate. The study was undertaken to provide three kinds of information. First to be determined was what combustible solid wastes were generated, where, and in what amounts. This information was to be obtained from the best currently available sources and projections made for the years 1980 and 1990. Its purpose was to provide information on waste supplies upon which to base any decisions to increase reliance on waste-derived resources. Second, the means for extracting resource values from these wastes was to be investigated. The feasibility of all extraction technology was to be assessed, the costs of each method of extraction were to be determined, and the markets for the extracted resource evaluated. Taking all these factors into account, the more promising technologies were to be identified as recommended candidates for research and development sponsorship by EPA. Finally, the study was to consider the different classes of actions that the federal government might take to encourage more widespread adoption of the recommended technologies so as to increase the recovery of resources from combustible wastes. In this last phase of the work, not only resource recovery, but actions tending to reduce the generation of combustible wastes were also considered. Possible alternative actions that tended to complement one another were grouped into strategies, their costs and probable effects estimated, and a preferred strategy recommended.

II. SUMMARY AND CONCLUSIONS

A. WASTES GENERATED

In 1970, U.S. combustible waste production from all sources was 810 billion pounds (dry weight). Of this, animal manure, forest residues, and fruit tree prunings made up 58 percent of the total; household and municipal wastes 21 percent; and commercial and institutional wastes 7 percent. The remainder was made up of sewage sludge, plant trash, and processing wastes from industrial and manufacturing activities. By 1980, the total combustible waste production is expected to be between 1121 and 1155 billion pounds, and, by 1990, between 1314 and 1459 billion pounds. If the higher figure is achieved, the United States will have twice the weight of combustible wastes to use or dispose of in 1990 as it had in 1970. In 1970 people living in metropolitan areas accounted for 68.6 percent of the municipal and household combustible wastes out of a total of 168.4 billion pounds. By 1990 metropolitan areas are expected to account for 80.8 percent of these wastes and the quantity of these wastes will have risen to 315.2 billion pounds. Partly as a result of population density changes land disposal sites for municipal and household wastes will have to be extremely remote, thus enhancing the viability of closer-in, less land-consuming methods for dealing with this waste burden, even if these alternative methods are more capital intensive than the relatively inexpensive land disposal methods commonly in use today.

Combustible solid wastes may be managed either through disposal methods, such as landfilling or incineration that do not seek to recapture values from the wastes, or, alternatively, resources may be recovered from these wastes. Whether or not resources are recovered from combustible solid wastes, the burden of waste management might be eased somewhat by measures designed to reduce waste production at the source or point of generation.

The alternatives of resource recovery and source reduction of wastes are not mutually exclusive. No waste reduction program will be able to do more than partially reduce the very large quantities of combustible wastes that are expected in the future. Some wastes may be more amenable to resource recovery than others. Many resource recovery processes, especially those that extract the more valuable products from mixed wastes, leave a substantial residue that requires disposal.

In view of the many parameters that influence the effectiveness of solid waste management, federal efforts in this area should not embrace any one approach to this problem, exclusive of all other solutions. More productively, it need only be decided in which areas the federal government can most beneficially expend its resources.

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B. TECHNOLOGIES FOR RECOVERY OF RESOURCES

The study reviewed the existing and projected technologies for extracting resources from various waste streams. These ranged from technologies that have been incorporated into full-scale operating plants to hypothetical waste utilization opportunities that may be projected from current laboratory research.

The technologies considered could be broadly described as those involving combustion, pyrolysis, chemical conversion, biological conversion, mechanical conversion, field spreading, and landfilling. The technologies were considered separately for the major waste streams that present significantly different characteristics: municipal waste, sewage sludge, and animal feedlot manure. Each of the identified technologies within these categories was evaluated in terms of five criteria: cost, amount of waste reduction, flexibility, current state of development, and natural resource conservation.

With respect to municipal waste, the evaluation process gave the highest ratings to pyrolysis, yielding an equivalent to #6 fuel oil, and combustion of shredded waste as a supplemental fuel in conventional coal-fired electric power generation plants. The choice between these two would be dictated by local circumstances such as proximity of plant sites to urban areas and whether available plant sites would admit or preclude large-scale waste deliveries. Pyrolysis has the advantage of being more flexible, that is, yielding a product that can be economically stored and transported in large quantities by conventional means. However, use of waste directly as fuel in power generation is a much more efficient form of energy utilization since pyrolysis uses up a large part of the waste's energy content in the pyrolysis process.

A second category of technologies, those for wet and dry paper fiber recovery, received somewhat lower scores because the resource they recover is a renewable one, present markets for the product are specialized and limited, and future markets still somewhat speculative.

A third class of technology that was favorably rated, but with a somewhat lower score than the two categories described above, was extraction of energy from waste-burning incinerators incorporating heat exchangers. Cost estimates indicated that in most cases such energy-recovering incinerators are more economically operated if the energy recovered is marketed as steam for space or process heat or cooling than if it is used to generate electric power.

The preferred technology for resource recovery from sewage sludge was spray irrigation or an equivalent form of land spreading, although in many locations incineration without resource recovery may be less expensive than land spreading.

For animal feedlot manure, pyrolysis in a system that would permit the recovery of the equivalent of #6 fuel oil was selected as the most promising technology.

C. RECOMMENDATIONS

1. Research and Development

Mixed municipal waste research should continue to hold the highest research priority over the near future. Animal waste research should receive increasingly greater priority over the next five years because of the projected increases in amounts and concentrations of animal waste and the impact on animal waste disposal of effective water pollution control enforcement. The following priorities indicate both relative priority in allocation of research and development resources and in the urgency of undertaking the research categories described.

First Priority:

Pyrolysis and utilization of mixed municipal wastes as supplemental fuel for coal-burning power plants.

Methodology to determine economic impact of incentive and disincentive measures.

Second Priority:

Sorting of municipal wastes.

Pyrolysis and incineration of animal wastes.

Standard setting related to waste disposal technologies.

Pyrolysis and incineration of sewage sludge.

Third Priority:

Classification of plastics by type and color.

Institutional opportunities for regional sanitary landfill planning.

Effects of user charges on waste generation and litter.

2. Federal Solid Waste Management Strategy

Federal action relating to solid waste management should concentrate on the problems related to mixed municipal refuse. Although the study of waste flows indicated that agricultural wastes are the largest single problem, the technology assessment indicated that technologies for the beneficial use, or environmentally acceptable disposal, of agricultural wastes were either in the development stage or soon could be. Although these technologies would add an additional cost to the production of meat, eggs, and dairy products, the costs are not great enough to disrupt existing patterns of consumption. Increasing population growth and urbanization of the population, however, will continue to increase the costs of sanitary landfill and require a combination of waste reduction and long hauls even in the presence of resource recovery programs. The resulting cost increases will not be controllable by the municipality, and they will increase per capita as the size of the municipality increases.

While the waste reduction and resource recovery technology assessment showed a marked difference between the more promising technologies described above and their less promising rivals, it also showed that resource recovery technology is still in the developmental stage; far enough along to guide research and development priorities, but not far enough advanced to determine with certainty that one or two technologies will clearly preempt the field ten to twenty years hence. It is, therefore, desirable that any federal incentive plan intended to promote improved waste disposal and enhanced resource recovery not be linked, by statute, to two or three specified technologies, but should be capable of utilizing whichever technologies are most promising at a given time and most suited to a community of a particular size and location.

The strategy that was selected provides for regulation of agricultural and industrial waste management by imposition of federal management standards governing disposal and resource recovery methods for each category of activity. It provides a subsidy of one dollar per capita per year to municipalities processing all municipal waste through approved waste disposal systems, sanitary landfill, pollution-free incineration, etc., and two dollars per capita per year to municipalities processing all waste through approved resource recovery systems. These subsidies are provided by a federal excise tax of one-tenth of one percent on the sale of goods. The proposed strategy is intended to encourage improved disposal of municipal wastes in relatively small communities where sanitary landfill is still practicable and where waste is generated in small enough quantities so that resource recovery is extremely expensive, and to encourage resource recovery in those large communities in which increasing urbanization is forcing up conventional disposal costs to the point at which they approach the costs per ton of waste of resource recovery processes.

In both cases the proposed subsidies would be intended to help encourage a municipality to adapt a preferred practice where the preferred practice is only marginally more expensive than the less desirable alternative course of action. Each would be intended to do so without directly penalizing or benefiting any one sector of the economy.

III. COMBUSTIBLE SOLID WASTE GENERATION

A. INTRODUCTION

This chapter is confined to a study of the generation, regional distribution, future levels, and special problems associated with major flows of combustible solid wastes (CSW). These topics were considered broadly, subject to some qualification. Minerals were not considered as combustible solid waste, even though coal mine tailings may contain as much as 10 percent unrecovered coal, because the technology for extracting the coal (at a price) is already mature and the resource, once recovered, would sell on an established market. Sulphur, which will be a very large volume byproduct of sulphur dioxide emission control by 1980, was not considered as a combustible waste because the sulphur oversupply will be a unique problem upon which an existing industry is already focused. Sewage sludge gave a special problem in definition. It is disposed of in concentrations that range from a few percent of suspended solids in a large volume of liquid to naturally or artificially dried solid material with a moisture content of 30 percent or less. It will support combustion at concentrations ranging between 12 and 20 percent depending on the combustion process. For purposes of the study, we have treated all sewage sludge as a combustible solid, and dealt with dewatering as part of the cost of processing this material.

Chapter III is a summary description of the amounts, distribution, sources, and future levels of combustible wastes generated in agriculture, manufacturing, and processing (including food processing), and in the combination of service, commercial, and residential wastes finding their way into mixed municipal refuse.

The structure of the analysis on which this study is based is given in Table 1 which is based on a classification description of economic activities. The listing of combustible solid wastes in this table is divided according to the major combustible waste-generating activities. The combustible materials flow analysis through the economy is described briefly here. The basic data makeup of the flows has been documented in this study and submitted to the Solid Waste Division of the National Environmental Research Center, Environmental Protection Agency, Office of Solid Waste Management Programs in the form of an extensive computer printout, (Table 91) which, because of its size, is not included in the text of this report. This "data bank" is in the form of raw data on individual product transactions and aggregated in the form of a model which describes the level of transactions (purchases, sales, etc.) of combustible materials among all economic sectors. Other tables contain product-by-product flows among all industrial waste generators, and details on the regional distribution of wastes.

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TABLE 1

MAJOR CONTRIBUTORS TO THE COMBUSTIBLE SOLID WASTE STREAM

A. Agricultural Wastes

- A-1 Wastes due to Animals; Manure, Bedding, Carcasses, Other
- A-2 Cultivated Plants
- A-2 Forest and Logging Residues

B. Manufacturing and Processing Residuals

- B-1 Wood-Related Wastes
  - Paper Industry
    - Pulp Mills; Paper and Allied Industries
  - Sawmill and Sawmill Products
    - Wood Remanufacture and Wood Products; Construction
- B-2 Textiles and Textile Products
- B-3 Non-Fiber Synthetic Materials
  - Plastic; Rubber
- B-4 Food Processing Wastes
  - Grains; Meat and Poultry; Fruit and Vegetable Processing; Sugar; Seafood
- B-5 Miscellaneous Manufacturing
  - Leather and Leather Products; Tobacco and Tobacco Products

C. Refuse and Sewage

- C-1 Household and Municipal Waste
- C-2 Sewage Sludge
- C-3 Commercial and Institutional Waste
- C-4 Manufacturing Plant Trash
- C-5 Demolition Waste

Although the combustible residuals with which this study is concerned are all disposed of as waste, there is a wide variation in the degree to which they constitute a waste disposal problem. "Quantity" alone is not a sufficient description of a CSW flow. Many other characteristics of these materials define their economic value, resource potential, and the special kind of waste disposal problem they pose. Local concentration, homogeneity, and collectability are important variables needed to characterize completely a combustible solid waste flow.

B. METHOD OF INVESTIGATION

The research performed under this study was partly conventional literature search and data gathering by field interviews and partly developmental application of input-output economic modeling techniques to obtain information needed for planning solid waste management programs. To the degree that the methodology was innovative, it is described here.

Input-output methodology was used to determine the magnitude of industrial combustible waste flows by industry, for the years 1967, 1980, and 1990. This consisted of the following tasks:

(1) Identify major combustible components of the solid waste stream;

(2) Identify activities that produce combustible waste materials and determine flows of combustible output;

(3) Determine coefficients of combustible waste materials produced per unit of output for the base year;

(4) Project combustible waste streams for years 1980 and 1990; and

(5) Allocate combustible waste streams among selected geographic areas.

The data used in undertaking each of these five tasks is described below; some information sources and data tabulations are attached as appendices.

1. Methodology Used in Research Task #1: Identify Major Combustible Components of the Solid Waste Stream

The methodology used in Task #1 consisted of examining the six digit material codes set forth in the 1967 Census of Manufactures,[1] Table 7A, "Material Consumed by Kind," to identify, by inspection, combustible materials flowing to industrial consumers. Agricultural materials were identified from the U.S. Department of Agriculture publication Agricultural Statistics.[2] Minerals, subsequently excluded from the study, were identified from the Bureau of Mines' Minerals Yearbook.[3]

2. Methodology Used in Research Task #2: Identify Activities that Produce Combustible Waste Materials

Task #2 consisted of grouping the combustible materials into five major categories representing SIC divisions. The major categories are as follows:

Category #1 - Division A. Agriculture, Forestry and Fisheries
Division C. Contract Construction
Division D. Manufacturing

Category #2 - Division F. Wholesale and Retail Trade

Category #3 - Division G. Finance, Insurance, and Real Estate
Division H. Services.

Category #4 - Division I. Government

Category #5 - Division J. Nonclassifiable Establishments (consisting for the purpose of this report of Households)

The purpose for this grouping was to identify activities that produce combustible wastes. Five different methodologies were used corresponding to the five categories enumerated above.

For Category #1 the activities that produce combustible waste were identified, as the materials had been, from the 1967 Census of Manufactures, Table 7A, "Materials Consumed by Kind." Consumption data on combustible material flows were transferred onto coding sheets designed for this purpose. The design of the coding sheets specified for each combustible material: (a) the consuming or the "buying" industry; (b) the supplying or the "selling" industry; and (c) the combustible material consumed. "Buying" industries on the coding sheets were identified by four-digit SIC numbers.

The code sheets contained the following information: (a) identification of the "buying" and "selling" industries by appropriate SIC numbers; (b) identification of the material consumed also by appropriate SIC numbers; (c) the value of the material consumed for years 1963 and 1967 in dollar terms; and (d) the magnitude of the material consumed for the years 1963 and 1967 expressed in physical units as reported in the Census of Manufactures.

Four problems that arose in the course of this effort require additional comments:

(1) The Census of Manufactures data contains no information on some combustible materials because the initial buying sector is included in Division A, Agriculture, Forestry and Fisheries, data for which is not reported in the Census of Manufactures. In order to obtain this data, another source of information was used--Agricultural Statistics, 1969.

(2) For each industry group (SIC four-digit code sector), some member companies reported only the total value of materials purchased, and did not report detailed data regarding specific materials consumed. These values were summed and listed under the heading "All other materials, parts and supplies, not specified by kind." Assuming that these companies purchased materials in the same relative proportions as those who submitted detailed data, the dollar value of "Materials..., not specified by kind" was distributed among the specific materials listed, and the physical quantity of each material increased proportionately.

(3) For some industries the materials consumed were shown only in monetary units. The physical conversion units of these materials were obtained from various other sources and estimates.

(4) Above data sources do not indicate combustible waste magnitudes resulting from plant trash. These have been estimated in a separate procedure described in Chapter III, Section E, and Appendix C.

Combustible wastes in Category #2 through Category #5 (as described above) result in almost all cases from disposal of waste, such as packing materials in wholesale and retail stores, food scraps from eating establishments, paper waste from offices, etc. The methodology used to determine all these activities and to estimate the magnitude of waste loads for these four categories is described in the attached appendices.

3. Methodology Used in Research Task #3: Determine Coefficients of Combustible Waste Materials for the Base Year

The ultimate objective of the research task was to determine combustible waste coefficients; that is, the magnitude of combustible waste per unit of material flow. Furthermore, it was also decided that the coefficient would represent that portion of

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combustible waste that is not used by the industry that generates the waste nor sold for profit to another sector of the economy. This definition of the problem was used throughout the report. No attempt was made to find other commercial uses or other ways to recover resources from materials that, while considered waste products in the process in which they are generated, are currently being used as fuel or sold on existing markets. The combustible waste coefficients represent the proportion of process residual that has zero or negative value.

The actual determination of the coefficient, therefore, consists of two steps. In the first step, all combustible waste resulting from activities or flows of combustible material was determined. In the second step, waste material used within the sector which generates waste or sold to another industry was determined and subtracted from the total waste. The difference then represents the actual waste as defined for this report.

The waste streams resulting from each activity were obtained from numerous sources, including published reports, engineering calculations, interviews with authorities in specific industrial areas and others. For each specific waste generation activity, more than one waste coefficient was obtained. These then were reported on the print-out forms obtained in Research Task #2 and compared for consistency and reliability. In the cases where the estimates varied markedly, additional information was obtained in order to explain the difference and one waste coefficient was decided upon.

As a rule, the procedure resulted in what we believe to be the most reliable available waste generation coefficients for almost all combustible waste generation activities. In three waste generation sectors, (a) waste from agricultural crops on the field, (b) wood products, and (c) pulp wood, some difficulties arise using this methodology because of a wide variety of procedures of the combustible waste handling for these sectors. For example, in the case of waste from wood products manufacturing, a large proportion of the waste is utilized as a source of heat and power in some establishments; other establishments do not dispose of this waste by incineration. Therefore, in these cases the waste coefficients were obtained by weighing the estimated number of establishments using specific waste handling methods against the industry's total. It is important to note that in some sectors it was determined that there is no waste of combustible material because any and all combustible materials which are not used up in the end product are either reused by the industry or disposed of by selling to other sectors. (For example, in the fats and oil manufacturing sector, all combustible wastes are either reused by the industry or sold.) At the conclusion of this task, all combustible waste coefficients were reported on data sheets, key punched on computer cards, and printed by the computer. Waste coefficients were checked in three ways. Total waste estimates derived from applying waste coefficients to flows were compared with estimates of total wastes appearing in the literature. With respect to industries for which we had detailed knowledge of all processes, we applied a material balance, subtracting known outputs from known inputs and comparing the result with the waste estimate based on interviews with processors. For most sectors, however, our principal means of validating estimates was by cross-checking the reports of a number of processors within a given industry.

4. Methodology Used in Research Task #4: Project Combustible Waste Streams for Years 1980 and 1990

The current data was organized along the very detailed economic classification categories of the Standard Industrial Classification system. In order to make ten- and twenty-year projections it was necessary to utilize one of the several existing models of projected U.S. economic activity. Such models display the anticipated activity in somewhat less detail than the SIC categories utilized for the current data; it was therefore necessary to aggregate flows and wastes into the broader categories used in the projection model. The input-output model utilized was that developed by Clopper Almon at the University of Maryland and previously modified by IR&T to include projections to the year 2000.[4] The following procedure was used to project the waste loads from the years 1980 and 1990. First, each combustible waste coefficient determined in Task #3 was related to a flow through a sector in the input-output table.

Second, it was determined whether forecasted growth in the sectors which resulted in increased combustible wastes was related to a rise in final demand as in industries manufacturing consumer products, or was also related to a rise in demand for one or several intermediate outputs, such as wood, within the input-output framework. If growth in the sector producing combustible waste was determined directly by final demand, the combustible waste projection for 1980 and 1990 rose in proportion to the anticipated growth in the final demand (e.g., food processing which sells directly to consumers). If, however, anticipated growth in economic activity resulting in combustible waste was partially dependent on intermediate outputs, projections of these were undertaken. In tracing the effects of increases in the intermediate outputs we examined the sequence of transactions connecting producers to users to determine where such increases would increase waste generations by both suppliers and users.

A detailed description of the projection task methodology and of the computer program through which the projections of flows and of waste generation was accomplished appears in Appendix A, along with the explicit materials flows and projections.

The projected combustible waste streams were based on two separate economic activity projections, and also on Bureau of Census "B" (high population growth rate) and "E" (low rate) projections for 1980 and 1990.

5. Methodology Used in Research Task #5: Allocate Combustible Waste Streams Among Selected Geographic Areas

Two independent allocation efforts were undertaken as part of this research task. In the first, all industrial combustible waste was allocated among the 173 Office of Business Economics (OBE) geographical areas (multi-county areas of relatively self-contained economic units). The procedure for allocating the combustible waste among the OBE areas are based on OBE's employment estimates showing employment by three-digit SIC code in each of the 173 geographic areas delineated. Estimates of national waste by industry were multiplied by each OBE area's percentage of national employment in each industry, to derive the amount of waste by industry and by OBE area. A detailed description of the methodology used, and current and projected waste levels are in Appendix D.

A second set of geographical allocations was made from a conventional literature search. The country was divided into four Census regions and a selected list of major industrial and agricultural wastes reported by region. Where any region accounted for more than 20 percent of the agricultural or industrial activity generating a given waste stream, data was reported by Census subregions; if a sub-region more than 20 percent, by state; if a state more than 20 percent, then by OBE areas. Appendix E describes fully the methodology used for this determination of regional wasteloads, and a few of the most important examples in which distribution is important.

Except in a few cases where there was an extreme geographical concentration of a given type of economic activity, the regionalization analysis offered little insight into problems caused by combustible solid waste. Certain sectors (e.g., municipal wastes) were analyzed on the basis of what would logically be "collection regions" (SMSA's). These regions, covering only about 11 percent of the United States land area, provide a meaningful regionalization of all industrial and urban-generated wastes. For certain manufacturing and agricultural sectors, the regional analysis was done to a level of detail dependent on the non-uniformity of the distribution of activity across the United States. These results are contained in Appendix E and the appropriate portion of this chapter.

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Appendix D derived from different sources and using a different method, shows total industrial wastes, by type of waste, for each of 173 OBE districts.

Flow Charts

Charts of materials flow and waste generation are included for the largest industrial CSW streams: forestry and wood products; pulp, paper and allied industries; rubber and plastics industries; textile and textile products; agriculture and food processing. These flow charts were drawn from numerical material contained in the appendices and, and therefore a connected visual display of the materials-consumed listing contained in the Census of Manufacturers.

Major components of each waste stream were followed from sector to sector as the combustible material underwent manufacture, decomposition, separation from unwanted portions, or any process which generated a residual. Each industrial manufacturer typically produces both for final users and for reuse in another industry. Products for final users (i.e., which were not to undergo subsequent manufacturing/waste generation) were not traced explicitly through wholesale, retail and consumption sectors, but were picked up again as disposed-of-after-use. Industrial waste flows terminate at the point where the combustible material is manufactured into its final form. Output to final users is indicated in flow charts, but quantities are not included.

In cases of wood products manufacture and pulp and paper producers, a large amount of the non-product is burned for fuel or disposed of in a resourceful manner--chemical recovery or sales to users of secondary materials. Wasteloads are consistently given in dry-weight content of waste and do not include the non-product materials which were not disposed-of-waste.

Minor flows have not been included. This adds to the simplicity of the display without generally detracting from the accuracy of the results. Also, each flow is for one material only, so that one type of economic activity may appear as a user of different materials (e.g., tire producers use rubber and textiles, wood pulp supplies feedstock to cellulosic fibres and textile, etc.).

C. NOTATION

Several conventions have been adopted in the following summary of combustible solid waste generation.

Dry Weight: All combustible solid waste loads were evaluated in terms of the dry solids content. This conversion was done to establish a uniform basis for the comparison of waste loads, and, for most purposes, dry solids content was the most useful parameter with which these loads can be described for purposes of resource extraction. Care was taken to avoid possible ambiguity by freely using the words "wet" to denote bulk or moist weight and "dry" to denote the dry solids content. The moisture content used for the conversion is usually given.

Waste Coefficient (w/c): Waste coefficients are defined as "the weight of dry, unused, combustible waste divided by the weight of input with its normal moisture content at point of input."

Let a = gross weight of material input;
b = gross weight of product output;
d = gross weight of residual; and d^* be the dry-solids weight of that residual;

then

$$a = b + d$$

$$a \cdot \text{waste coefficient} = d^*$$

In the section on plants cultivated for food, an exception was made, and waste is related to production (output):

$$\text{i.e., waste coefficient} = d^*/b.$$

This distinction was made because all data relating to agriculture and forestry is given in terms of output rather than input, and this form would therefore be more useful.

Throughout this chapter, the following abbreviations have been used:

B = billion
M = million
lb = pound
cu ft = cubic feet
bd ft = board feet

All units of measure for weight have been converted to pounds by use of the appropriate conversion factors.

D. SUMMARY: WASTE LOADS, TRENDS, FLOWS OF IMPORTANCE

This section summarizes the fundamental data and concepts of solid waste generation.

Total combustible solid waste generated nationally was estimated to be more than 800 B lb for 1970, based on an analysis of all major industrial, municipal and agricultural solid wastes sources. By 1980, this total is expected to rise to more than

1120 B lb, an increase of 40 percent in ten years. Total CSW in 1990 can be expected to be 70 percent greater than the amounts to be dealt with today. (Crop residues have been excluded from these totals for reasons described in the text in Section E of this chapter.)

Each component of the waste stream, however, appears to be amenable to a specific type of attack: legislative, technological, or economic. This summary provides general descriptions of the most important components of the CS wasteload, present levels and future trends, and characteristic of the waste/waste stream of importance to abatement of that waste.

Total volumes of waste, by themselves, offer only a partial insight into the total CSW picture. The question "How Much?" often must share importance with 'Within what region...?". Wherever possible, an attempt has been made to describe the burden which these wastes create, and to emphasize differences in individual waste streams which would make one a more likely candidate for abatement than another. It is important to keep relative amounts, and localized, collectable amounts, a primary consideration. Environmental burden is another consideration which has been emphasized--a ton of manure in a feedlot raises different problems than a ton of manure distributed over open pasture.

If the total CSW is divided roughly into that of agricultural origin (including forestry and animals for food), industrial origin, and urban activities origin, some general characteristics can be attributed to each of these gross categories.

Agricultural Wastes: The biggest problems in the classification of agricultural wastes are the tremendous concentrations of manure generated by animals raised in confined conditions--more specifically, cattle feedlots. Other agricultural wastes, while still burdensome, are relatively small in comparison. Feedlots themselves are a relatively new phenomenon, growing into a problem mostly in postwar years. Though feedlot population has doubled since 1959, the rate of growth has leveled off in recent years because of increasing environmental concern voiced by the public. This concern has often found its way into constraints on free-wheeling feedlot cattle production, i.e., legislation pertaining to permissible location of feedlots, disposal of manure, treatment of liquid runoff, etc.

Present disposal methods for feedlot wastes center around landfill, either with or without earth cover. However, even "sanitary landfilling" of large quantities of animal wastes has undesirable consequences, especially on the level of water purity in nearby areas. Current feedlot waste disposal practices continue to pose both a sanitation problem and an annoyance to nearby population centers. Cattle feedlots generate 42 B lb (dry weight) of manure annually, and about 200 B lb as generated in wet form.

Each year dairy cattle and poultry concentrations produce approximately 20 B lb and 13 B lb of dry weight manure, respectively, but because confined populations are generally smaller, wastes are not nearly so burdensome as are those of cattle feedlots. Logging residues, though estimated to be 52 B lb annually, are dispersed and relatively inaccessible, though uniform application of the best techniques of forest management could reduce this amount considerably.

The largest contributors to industrial CSW are pulp mill wastes and sawmill waste. Industrial Pollution abatement is a very active area, and waste generation rates are in a state of flux because of pressure applied by concerned environmentalists. Industrial waste generators have been the first to feel the effect of environmental legislation. Even in the last two or three years, wastes from pulp, paper and sawmills have dropped drastically, and are projected to continue to decline into the foreseeable future as existing technologies are applied.

Note: The question of CSW reduction through legislation (where the technological means existed) was rather difficult to quantify. Though considerable progress has been achieved in this area in the last 5 years, and promises to continue for at least as long in the future, legislative pressure on polluters is very sensitive to public attitudes and pressures. This uncertainty of the future of abatement-through-legislation was incorporated cautiously in the wasteload projections. Pulp, paper, and sawmill waste levels were projected to decline as a proportion of materials processed even with rising output, i.e., decreasing "waste coefficients." Waste coefficients for other industries were not defined to be time variant explicitly, but were generally weighted more in the direction of "technologically achievable" levels than "level as currently implemented" (the latter always being greater than the former).

Municipal refuse (defined here to include municipal, commercial, and institutional refuse) poses a special problem. Total per capita urban generated combustible waste generation is now estimated at 4.4 lb each day, and is expected to increase more than 50 percent in the next twenty years. The total urban generated wasteload of CSW (1970) was calculated to be 254 B lb to rise to 446 B lb by 1990.

Municipal sewage is subject to the same three problems as is urban refuse: increasing per capita generation, resulting from an increase in the proportion of the population served by several waste treatment systems, and increased use of garbage disposals; increasing population; and increasing urban concentrations. Added to these are the increasingly strict levels of allowable contaminant, which, by requiring uniform secondary treatment and eventually tertiary treatment, will also add fractionally to the sludge residue to be disposed of.

Focusing now on the largest CSW flows, and summarizing present and projected development, it appears that among agricultural wastes, feedlot manure is a very great problem without an adequate solution, with a stable or slowly increasing level of generation expected. Industrially generated combustible solid wastes are now and will continue to be driven downward by current and proposed legislation, with the rate of decline contingent only on the availability of economical technology. Further, the largest generators, pulp and sawmills, are decreasing generation most rapidly. Urban wastes of all types are expected to continue their increase.

Table 1 shows in greater detail the various components of the CSW stream. Each flow is described in the appropriate section, including:

1. Waste level--amount 1967 (1970)
2. Projected amount--1980, 1990
3. "Waste Coefficient"
4. Regional distribution, where important
5. Material flow diagrams

Table 28, included in this chapter's summary, is a numerical tabulation of present and projected waste loads. Appendices A through E, attached contain descriptions of methodology, regional distribution of industrial wastes, and the computer model of materials flows.

E. FLOW-BY-FLOW DESCRIPTION OF COMBUSTIBLE SOLID WASTES (CSW)

1. Agricultural Wastes

a. Animal-Generated Wastes (SIC 013x-014x)

i. Animal Manure

Livestock and poultry produce annually approximately 2280 B lb of manure wastes (411 B lb dry weight content). Three-fourths of this is due to dairy and beef cattle, with poultry, hogs and sheep contributing most of the remainder. These wastes have become a waste disposal problem because of recent trends toward large cattle and hog feeder lots, and poultry farms. These animal concentrations invariably produce much larger amounts of wastes than can be absorbed by surrounding markets for fertilizer or fill. Since World War II, handling costs of manure and relatively inexpensive chemical fertilizers have combined to reduce severely the demand for animal wastes as fertilizer (see Table 2).

TABLE 2

COMBUSTIBLE WASTE DUE TO LIVESTOCK AND POULTRY

Animal	1967 Daily Population[a]	Unit Waste Rate[b]	Dry Waste
Dairy Cattle	22.9 Million	3705 lb (dry)/year	84,900 M lb
Beef Cattle	85.7 Million	3234 lb (dry)/year	277,000 M lb
Hogs	53.2 Million	328 lb (dry)/year	17,800 M lb
Sheep	23.9 Million	365 lb (dry)/year	8,700 M lb
Broiler Chickens	450 Million	9 lb (dry)/year	4,050 M lb
Layer Chickens	428 Million	22.6 lb (dry)/year	9,700 M lb
Turkeys	52 Million	25 lb (dry)/year	1,300 M lb
Horses			7,000 M lb
Ducks			800 M lb
Condemned Poultry and Livestock			2,000 M lb
Total Wastes Due to Animals			413,250 M lb

[a] Daily population, either (a) population January 1, 1967 or (b) number processed during year x lifetime - (fraction of year): 9 weeks broiler, 6 months turkey.

[b] Waste rates are for animals representative of species population. Dry weight/wet weight for manures are approximately 0.16 (cattle), 0.25 (poultry), 0.10 (sheep), 0.05 (hogs).

Source: Personal communication from Dr. Lou Smith, U.S. Department of Agriculture, Poultry Research Division, Beltsville, Maryland, to Lane Mason, International Research and Technology Corporation.

Of this 413 B lb of wastes, less than one-fourth occurs in sufficient concentration to make collection and disposal necessary and/or economical. Although 70 percent of cattle are eventually marketed through feedlots, each stays in the lot for a relatively short time preceding slaughter (90- to 200-day feeder period in 1-1/2- to 2-year lifespan). The cattle feedlot population was 11.3 million head on January 1, 1967 and had risen to 13.2 million head by January 1, 1972 (see Table 3).

TABLE 3

CATTLE ON FEEDLOTS (000)

January 1, 1967	11,268
January 1, 1968	12,417
January 1, 1969	12,534
January 1, 1970	13,190
January 1, 1971	12,762
January 1, 1972	13,200

Source: U.S. Department of Agriculture, *Agriculture Statistics*, U.S. Government Printing Office; and private communication, U.S.D.A. for 1972 data.

Listed in Table 4 are estimates of the fraction of manure which is generated in cattle feedlots (including dairy cattle), and in the commercial production of chickens for eggs or meat.

TABLE 4

MANURE GENERATED IN CONCENTRATED CONDITIONS (1967)

	Mean Daily Population	Dry Wt/Unit Year	Total Weight
Dairy	5.7 million	3,705 lb	20.3 B lb
Beef Cattle	11.3 million	3,720 lb	42.0 B lb
Broiler Chickens	450 million	9 lb	4.1 B lb
Layer Chickens	428 million	22.6 lb	9.7 B lb

Source: Based on estimates by staff, International Research and Technology Corporation, December, 1971.

Although it is estimated that all chickens are raised in dense concentrations, 25 percent of each dairy cattle year is in concentrated regions. The beef cattle feedlot population is a U.S.D.A. statistic. Feeding methods in a controlled feedlot situation generally produce higher waste rates per animal. A concentration of dairy cattle of 1,000 head (reasonably large) would generate 3.7 M lb per year and 100,000 chickens 0.9 to 2.26 M lb per year, indicating that the highest concentration will be in cattle feedlots, whose distribution by size is given in Table 5. Cattle on feedlots of more than 1,000 head each account for 90 percent of total cattle on feedlots.

TABLE 5

CATTLE FEEDLOT--SIZE DISTRIBUTION
(January 1, 1972)

Size (Head of Cattle)	Number in that Size Range
More than 32,000	44
16,000 - 31,999	116
8,000 - 15,999	206
4,000 - 7,999	324
2,000 - 3,999	537
1,000 - 1,999	977

Source: Personal communication from Mr. Hannawald, U.S. Department of Agriculture, Packers and Stockyards Division, March 1972, to Lane Mason, International Research and Technology Corporation.

ii. Other Livestock Wastes

Livestock deaths not due to meat production constitute another source of livestock-generated wastes, but because of current disposal methods and random distribution, it is not expected that this flow constitutes a significant recoverable resource (Table 6).

These carcasses would have a dry solids content of not more than 2 B lb, i.e., small compared with other livestock-generated wastes.

Disposal methods vary depending on cause and place of death--those dying in areas of relative concentration (chicken ranches) are handled in a more uniform manner than other carcasses, whether it be by burning, or by-product extraction (pet food or fertilizer).

TABLE 6

LIVESTOCK DEATHS (1967)

Species	# (000)	Est. Wet Weight
Cattle	1,525	1,670 M lb
Calves	2,513	1,250 M lb
Hogs and Pigs	6,306	1,800 M lb
Sheep	1,992	300 M lb
Lambs	1,658	170 M lb
Poultry	---	367 M lb
		5,557 M lb

Source: U.S. Department of Agriculture, Agricultural Statistics - 1968, U.S. Government Printing Office, Washington, D.C.

The most problematical animal wastes, those from large cattle feedlots, are concentrated mainly in the North Central sections of the United States, in the same regions as feed grains are produced. In addition, large feedlot populations are found in Texas, Colorado and California. It has been projected that feedlot capacity in the West South Central (Texas and Oklahoma) and Mountain States will continue to increase at the expense of the more established areas in Iowa, Nebraska and Kansas, which together supplied 40 percent of feedlot cattle in 1970. Appendix E gives the regional distribution of cattle in feedlots.

b. Crops Cultivated for Food; Tobacco; Cotton (SIC 011x-012x)

Most post-harvest plant residues are pulverized and plowed under. Some are burned. The proportion plowed under is likely to increase, because burning laws in many locales are being tightened. In most cases, the plow down is beneficial to future crops (humus, nitrogen, trace elements), although it often contributes to pesticide build-up in the soil. Whether or not field residues from plants (not including trees) constitute waste or a resource is a question of relative economics. All agricultural residues are listed here for added flexibility and completeness.

Fruit tree prunings, contributing 2-3 B lb of residues annually, are generally burned because the value and economic feasibility of other methods of disposal are different than they are for field crop residues (longer time to decompose, difficulty in pulverizing and mulching, constraints of existing trees, unlike field crops where the plant is completely mixed with the earth).

Table 7 lists basic sources of field residues generated by agricultural activities, not including forestry.

TABLE 7

AGRICULTURAL RESIDUES (WET WEIGHT)

Grains	784,000 M lb
Cotton	30,000 M lb
Tobacco	1,000 M lb
Fruits & Vegetables	32,840 M lb
Fruit Tree Prunings	2,500 M lb
	850,340 M lb

Source: Summation of individual crop production and waste generation, using waste coefficients for crops gathered from literature and personal sources by International Research and Technology Corporation, October 1971 - January 1972.

Only 2,500 M lb (Fruit Tree Prunings) is currently handled as waste, i.e., with no attempt to extract a resource from it. Tables 8, 9, and 10 show the field residual situation for each individual crop. The list is not complete, but accounts for more than 99 percent of the annual agricultural harvest.

Whether or not agricultural field residues constitute a "waste" flow is a matter of definition, except for fruit tree prunings, which are generally regarded as problem wastes, and are disposed of as such.

Otherwise, the decision to plow under, burn in place, or treat field residues (not tree prunings) as waste is dependent on:

1. soil beneficiation
2. pesticide build-up
3. costs of collection and disposal
4. risks of pest infestation
5. restrictions on burning

Recently, the balance has shifted definitely toward a partial resource extraction through plowing down almost all crop residue.

TABLE 8

FIELD RESIDUES--GRAINS, FIELD CROPS, TOBACCO, COTTON

Crop	Acres (000)	B lb Produced	lb/Acre Wet Waste Rate	B lb Residues (Wet)	Waste Coeff.[a]
Barley	9,117	17.9	4,000	36.7	0.820
Corn	69,978	26.7	6,200	376.0	0.554
Corn Silage	8,343	188.4	500	4.2	0.010
Oats	16,017	25.2	3,650	58.5	0.960
Rice	1,970	8.9	6,800	13.4	0.378
Rye	1,071	1.36	4,000	4.1	1.210
Soybean	14,999	42.4	3,400	51.7	0.488
Soybean Forage	2,381	8.52	3,400	7.3	0.351
Soybean Silage	1,031	20.36	400	0.4	0.008
Wheat	58,771	91.5	1,850	108.0	0.472
Soybeans	39,767	58.5	2,000	79.5	0.544
Dry Beans, Peas	1,500	1.8	3,000	4.5	0.957
Hay	64,667	252.6	--	--	--
Seed Crops	1,909	.450	4,000	7.6	0.450
Peanuts	1,402	2.47	2,300	3.4	0.579
Sugarbeet	1,122	38.4	6,400	7.1	0.074
Sugar Cane	634	53.3	55,000	17.2	0.129
Potatoes	1,458	30.5	2,300	4.4	0.058
Sweet Potatoes	147	1.37	2,300	0.34	0.123
Cotton	7,997	3.74	3,760	30.0	3.200[b]
Tobacco	960	1.968	1,050	0.978	0.198
	305,301	1,116.6		815.4 326.2 (dry)	

[a] Waste coefficient for cultivated crops is defined: (dry weight residual/weight produced). For residues listed in this table. moisture content estimated at 60%; i.e., w/c = 0.4 R(w)/P. (P = weight of production and R(w) = weight of wet residue.)

[b] In the case of cotton, in addition to 3.74 B lb cotton produced, 6.270 B lb cottonseed constitute an additional cash crop. The waste coefficient appearing here is computed on the fiber crop alone. Including both cotton and seed, the waste coefficient becomes 1.19.

Sources: Acres harvested: data from Agricultural Statistics, 1968. Residues: Idaho Solid Waste Management 1970: Status Report and State Plan, Idaho Department of Health, 1970; National Science Foundation, private communication.

TABLE 9

FIELD RESIDUES--FRUIT TREES

Crop	M lb Produced	Wet Residue (M lb)	Dry Waste Coefficient
Apple	5425.	2430.	0.090
Prune	478.	134.	0.056
Cranberry	140.	28.	0.040
Grapefruit	4280.	860.	0.040
Lemon	1361.	272.	0.040
Lime	33.6	6.7	0.040
Orange	16500.	3300.	0.040
Grape	6138.	1270.	0.040
Plum	196.	55.	0.056
Peaches	2691.	752.	0.056
Pear	926.	185.	0.040
Strawberry	478.	95.	0.040
Apricot	296.	82.6	0.056
Total	38942.6	9470.3 1894.1 (dry)	

Moisture content of residue = 80%

$$\text{Dry Waste Coefficient} = \frac{\text{(Dry Weight Residues)}}{\text{Weight of Produce}}$$

Sources: Production: Agricultural Statistics 1968, U.S. Department of Agriculture, U.S. Government Printing Office, 1968. Residue: Personal communication from National Science Foundation to Lane Mason, International Research and Technology Corporation, November 1971.

TABLE 10

FIELD RESIDUE--VEGETABLES AND MISCELLANEOUS CROPS

Crop	Amount Produced (M lb)	Residue (Wet M lb)	Waste Coefficient (dry)
Asparagus	300.4	700.	0.467
Beets	442.	100	0.045
Broccoli	278.2	400	0.288
Brussel Sprouts	68.5	100	0.292
Cabbage	2500.	600	0.048
Carrot	1770.	1200.	0.136
Cauliflower	242.8	100.	0.082
Celery	1533.	300	0.039
Cantaloupe	1250.	500	0.040
Honey Dew Melon	157.	44	0.056
Lima Beans	260.	800	0.615
Snap Beans	1635.	4700	0.571
Fresh Corn	4518.	4500.	0.199
Tomato	12438.	2500.	0.040
Cucumber	1689.	500.	0.059
Lettuce	4275.	1200	0.056
Onion	2880.	1800	0.125
Green Pepper	435.1	100	0.046
Spinach	402.6	330	0.164
Peas	1188.	1800	0.303
Watermelon	2770.	1100	0.079
Totals	41032.6	23374 4675 (dry)	

Moisture content of residue = 80%

$$\text{Dry Waste Coefficient} = \frac{\text{Dry Weight Residue}}{\text{Weight of Produce}}$$

Sources: Production: Agricultural Statistics, U.S. Department of Agriculture, U.S. Government Printing Office, 1968. Residue: Idaho Solid Waste Management 1970: Status Report and State Plan, Idaho Department of Health, 1970.

c. Forest and Logging Residues (SIC 0811)

Logging operations in 1967 left approximately 52,000 M lb (dry) of forest residuals. Total timber cut that year was 11,460 billion cubic feet, to meet a range of demands (Table 11).

Most estimates of in-forest logging debris are about 1 ton of debris per 1,000 board feet of merchantable lumber, although an Oregon survey uses 0.75 ton per 1,000 board feet.[5] Production of lumber in 1967 was 35.3 billion board feet, indicating a net forest residual of 53,000 M lb for this activity (using the Oregon figure). In addition are residuals left from wood cut for other purposes. The rate of debris generated depends on the use to which the timber is put, e.g., fuelwood, fenceposts; other miscellaneous uses will be less selective as to the size and/or quality of timber used or about 15 percent of the total forest material affected (logged plus residue). Using a 55 percent dry basis factor (45 percent moisture) yields a net forest residual of 52,000 M lb, dry weight. Table 12 lists the amount of logging debris from various sources.

In 1962, mortality of growing stock due to fires, insects, disease, and natural causes totaled 5.63 billion cubic feet, or about half the amount that was cut for commercial use.[6] Less than 10 percent was salvable because the dead wood is rarely localized enough to make logging economical, and the lumber was often of poor quality.

Unfavorable economics prevent more thorough use of forest residues, which are often inaccessible and have a much higher fraction of unusable bark, knots and vegetation than the material logged out. Chipping costs average about $12 per ton, compared with burning at $1 per ton.[7]

Projections of forest residuals, based on a similar waste generation rate in the future, are between 55 B lb and 62 B lb (1980) and between 71 B lb and 90 B lb (1990), based on population projections described in Appendix A.

2. Manufacturing and Processing Wastes (SIC 19xx + 39xx)

a. General

Manufacturing process wastes include all residuals generated from material inputs which leave the plant as a product output. It includes the residuals from a block of wood shaped into a piece of furniture, but not the cardboard carton in which the block of wood arrived.

TABLE 11

USES OF TIMBER HARVEST

1.040 B cu ft	Fuel Wood
5.470 B cu ft	Sawtimber
0.315 B cu ft	Log exports
1.045 B cu ft	Veneer
3.090 B cu ft	Pulp Wood
0.500 B cu ft	Other Uses
11.46 B cu ft	

Source: U.S. Department of Agriculture, Forest Service, The Demand and Price Situation for Forest Products 1969-1970, miscellaneous publication No. 1165, Table 2, page 44, March 1970.

TABLE 12

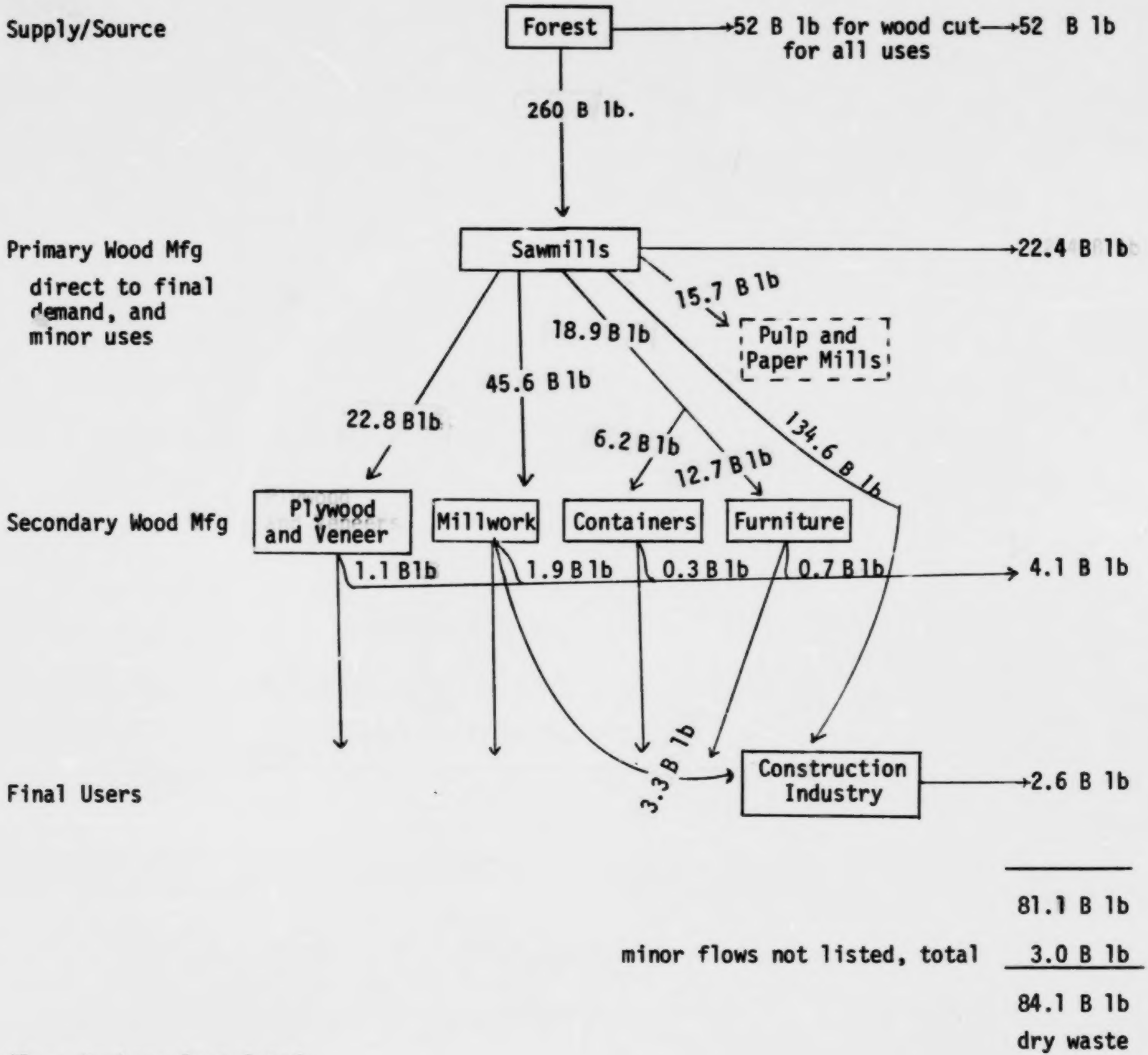
LOGGING DEBRIS (1967; WET)

Use	Est. Debris (M lb)
Fuel Wood	3,000
Sawtimber	53,000
Veneer	11,000
Pulp	24,000
Log Exports	3,000
	94,000

Source: Estimates by International Research and Technology Corporation, based on information contained in Solid Waste Management Practices: Oregon State Report 1969, by Solid Waste Section, Oregon State Board of Health, Portland, Oregon, Culham, W.B., G.F. Beachler, B.B. Bailey, and R. Sorenson.

FIGURE 1

MAJOR SOURCES OF WOOD WASTES (1967)



Almon Numbers Associated:

8	Forest
41	Sawmills
42	Plywood & Veneer
43	Millwork
44	Containers
45/46	Furniture
19/200's	Construction

(Waste Amounts Indicated by Arrow to Right →)

Industries usually generate process waste of homogeneous composition. They have been quite effective in utilizing primary residuals (generated from main product manufacture) in an economically beneficial manner. The amount of residuals generated are rarely equal to the amount of residuals disposed of as waste. However, the fraction of the residual which can be disposed of economically varies among different types of economic activity. The waste coefficients used in this report account for only those residuals which are disposed of as waste.

Several major trends are taking place which will affect residual generation and use for by-products. All major indicators point to increased sale or in-house use of residuals, less burning, and lower waste generation rates.

(1) Laws - Laws restricting burning and disposal of waterborne wastes drive these wastes elsewhere--often out of the waste category into the by-product market, perhaps without positive economic return but still the least expensive means of disposal (possibly still "waste" in terms of definitions used in this report).

(2) Economics - Industries can no longer afford to generate such large quantities of residuals which bring no economic return--now that methods for reducing waste exist. The apparel industry is generating less waste per unit output, and the wood industry is finding more use for its residuals.

(3) Plant Size - Due to costs of collection and transportation, larger plants produce quantities of residuals which are usually more marketable than those produced in smaller plants. The trend toward larger production units will bring with it a more thorough use of residuals.

(4) With the exception of synthetic materials (plastic, synthetic rubber, synthetic fibers, etc.), industries handling combustible materials have reached a level of maturity and stability, a level of efficient and refined processes, that the place to look for further economies will be more in the area of residuals use rather than in already settled production processes.

In most manufacturing sectors, a variety of materials can and do generate process waste. The rubber tire industry generates cord and fiber waste in addition to rubber. Wood, textile, rubber, and plastic waste are generated in the manufacture of furniture. But although each species of waste appears as process waste in many sectors, and many species appear in each sector, it is nevertheless true that the process waste from each sector is usually dominated by one species of residue. For purposes of waste handling and resource extraction, it is much more important to know "total process waste generated in the apparel manufacturing industries" (which is predominantly textile) than it is to know total textile waste generated in every industry, e.g., apparel, furniture, automobile seat covers, leather goods. The location of residuals is a much more meaningful basis on which to catalog wastes than type of material. This tends not to be the case to the extent that one kind, by virtue of improved economies, distinguishes itself and makes its separation from all waste flow feasible and desirable. Collection and disposal generally proceed from plant to plant and not from species to species.

In each of the manufacturing areas discussed below, the title indicates (1) the manufacturing process involved, (2) the dominant kind of process waste, and (3) to varying degrees, the total amount of that waste generated in every sector.

As noted above, waste generation coefficients often showed considerable variation, depending on a number of plant-operation variables. Each waste coefficient has to be considered in light of the following questions because materials may be treated as valuable by-products or process wastes depending on the answers.

(1) Is the waste contaminated? (If not, it may be recovered as by-product instead of disposed of.)

(2) Could the waste be used as fuel? (Local laws and demand for fuel must be considered.)

(3) Would there be a market if the quantity were larger? (Economies of scale affect saleability of some wastes, especially sawmill.)

(4) How large is the plant? (Same as above.)

(5) What are current and anticipated disposal methods?

(6) What are trends in technology?

It is important to note that only in the Primary Wood Manufacturing sectors (parts of SIC sector 24) and in the Wood Pulp Manufacturers' sector (SIC 2611) is the ratio of process waste to plant trash large (about 100:1 in each case). The amounts of process-generated wastes in these two areas are dropping rapidly. Several other industries lie in the range 1:1 to 4:1 (Process Waste: Plant Trash), which include Meat and Meat Products (SIC 20)--1:1; Textile and Textile Mill Products (SIC 22)--1:1; Apparel (SIC 23)--1:1; Furniture (SIC 25)--4:1; Printing and Publishing (SIC 27)--2:1. The remaining sectors, because they do not use combustible materials in their manufacturing processes, have much more combustible plant trash generated than process waste. Appendix C gives a summary of plant trash generation.

b. Wood-Related Wastes

i. Pulp, Paper, and Allied Industries (SIC 26xx)

The combustible wastes generated by the pulp, paper, and printing industries are basically of two types: (1) a chemical-saturated, lignin-binder sludge from pulping processes and (2) unusable paper wastes generated from converted paper and paperboard products manufacture and from printing. A materials balance through the initial pulp wood to wood pulp and primary paper manufacturing processes indicates that only about 50 percent of dry-weight pulp wood inputs leave paper manufacturers in paper or paperboard form. The remaining 50 percent, in a solution containing about 16 percent dissolved solids, is then handled in various ways depending on the pulp process.

Wood Pulp Manufacture. Total pulp wood consumption (including pulp wood equivalents of waste paper, board and miscellaneous fiber inputs) was 64.2 M cords in 1967. In 1967, round wood, wood chips, and pulp wood imports accounted for 55.8 M cords,[8] for an estimated total wood input weight of 140 B lb (dry) (4,500 lb/cord fresh cut at 45 percent moisture content).

Of this 140 B lb, one-half (70 B lb) is produced as wood pulp. The remainder is disposed of in the process of chemical recovery, for use in by-products, sewered, dried, and land-filled, or burned for fuel.

Table 13 gives a summary of wood pulp production (1967) and waste generation, by process of production.

18.2 B lb dry solids residue generated from an input of approximately 251 B lb (wet) implies an average pulp mill "primary residual fraction" of .072, although very dependent on the pulping process used. The Kraft process, which burns all combustible residues in its chemical recovery cycle, is largely responsible for such a low residual generation rate for an industry which has a solids output equal to only half of its input.

Limited markets exist for certain by-products obtainable from wood pulp residuals (e.g., vanillin, turpentine, tall oil, and an asphalt-like road conditioner) but the demand is met using only a small fraction of the residues. Furthermore, there are chemical recovery schemes for sulfite processing, the growing extent of which has not been accounted for in Table 13. The residue listed

TABLE 13

WOOD PULP PRODUCTION AND RESIDUALS (1967)

Process	Input (B lb)	Output (B lb)	% of Total Wood Pulp	Yield	Residual (B lb)
Kraft	100.3	45.2	63.6	45%	2.5[a]
Groundwood	8.0	7.8	11.0	100%	0.2
Semi-Chemical	7.7	6.6	9.3	80%	1.1
Sulfite	11.4	5.4	7.6	50%	6.0
Other	14.4	6.0	8.5	50%	8.4
Totals	141.8	71.0^5	100.0		18.2

[a] Pulp residue burned in chemical recovery accounts for remainder.
Wood pulp yield is 40-45%, remainder is used in by-products.
Residual calculated from information in cols. 1-4.
An additional 20 B lb wood pulp is produced from domestic and imported waste paper.

Source: Marketing Guide to the Paper and Pulp Industry, Charles H. Kline and Co., Inc., Fairfield, N.J., 1968.

above, therefore, is to be viewed as a maximum, dependent on the fraction of sulfite residue which is destroyed in the process of chemical recovery.

Some sulfite processes, faced with decreasing economies caused by discarding expensive process chemicals, have adopted the chemical recovery cycle above, which, like the Kraft recovery cycle, burns combustible portions of the residue in order to extract chemicals. Others, faced with the same dilemma, have found it necessary to terminate their operations. It is expected that future pulp mills using the sulfite process will find it increasingly difficult to operate without a chemical recovery cycle.

Other definite trends which affect the generation of combustible residuals by the industry are: (1) increasing public pressure to curb pollutants, both those who burn their residues and produce noxious fumes, and those who discharge their materials into sewers and lagoons; and (2) a rapid growth in the use of the low-residual Kraft process. (The last 35 years have brought Kraft process wood pulp into the dominant position in the market--64 percent--and it is expected to experience the fastest growth in the future.)

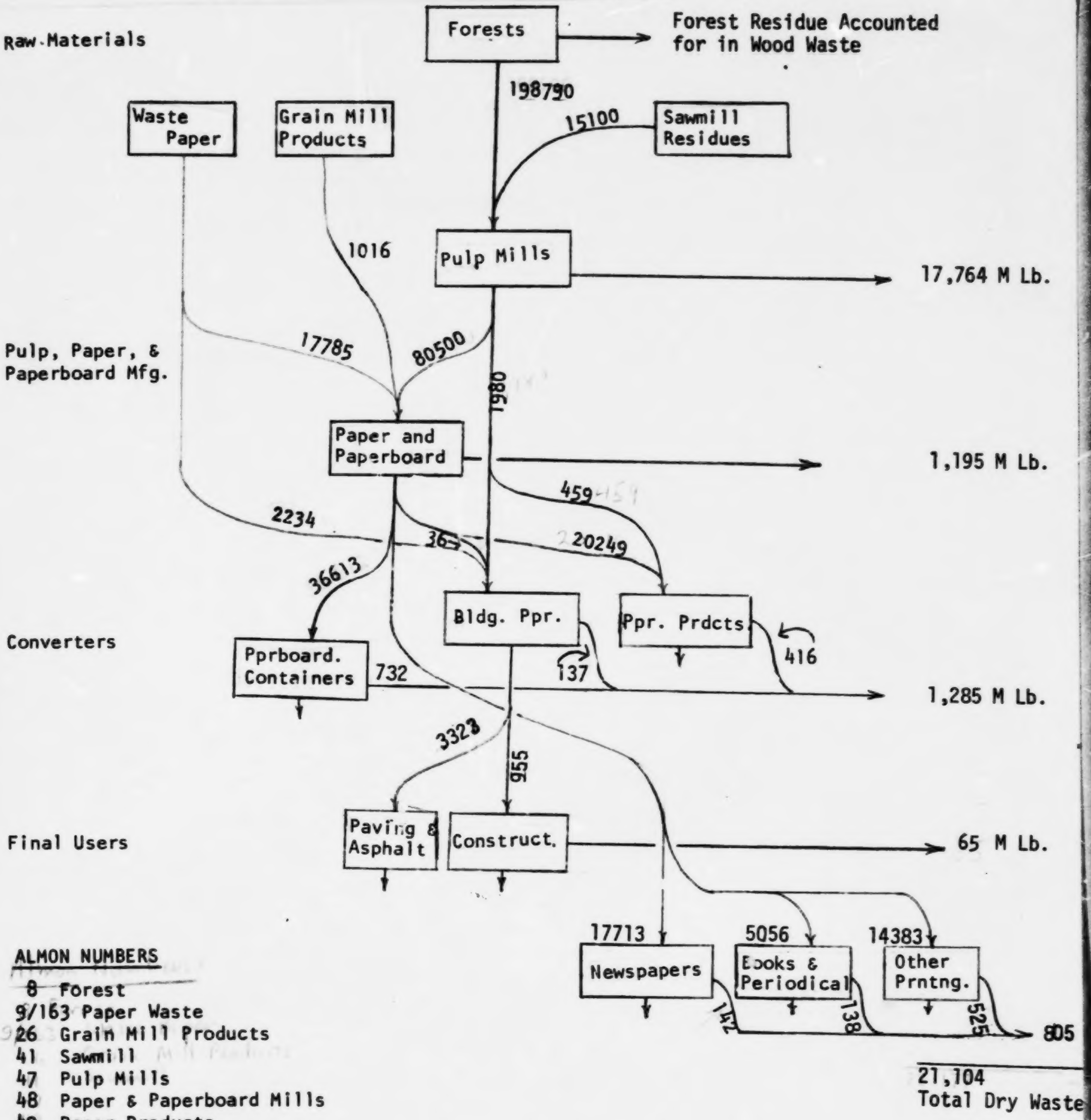
These three trends: economies of sulfite chemical recovery, changing public attitudes toward pollution, and the increasing share of the wood pulp market being taken by low-residual Kraft processing, all indicate that mechanisms already in motion will be effective in reducing greatly the amounts of residuals generated by pulp and paper mills. For this reason, the waste level of pulp and paper manufacturers in 1990 can be expected to be about half the 1967 level, even though the output from the industry will have more than doubled in that time (see industry summary contained in Table 28).

Converted Paper and Paperboard Products; Printing (SIC 27xx). Unused and unusable paper residuals from these industries totaled 2080 M lb in 1967. These residuals consisted of contaminated (glue or ink mainly) paper, and unusable paper and board clippings. Wastes are generated in a number of activities (listed in Table 14).

Salvability of converted paper and board processing wastes is estimated at 80 percent (i.e., there were about 10 B lb of residuals before salvage) and those unusable are contaminated by one or more substances, glues, or inks. Most clean, homogeneous paper industry wastes are recyclable. The 2 B lb unusable are burned or disposed of in a manner similar to commercial waste.

FIGURE 2

MAJOR PAPER RELATED WASTES; INDUSTRIAL PAPER WASTE
(M Lb.; 1967)



ALMON NUMBERS

8	Forest
9/163	Paper Waste
26	Grain Mill Products
41	Sawmill
47	Pulp Mills
48	Paper & Paperboard Mills
49	Paper Products
50	Building Paper Mills
51	Paper
52	Newspapers
53	Books and Periodicals
54	Other Printing Services
71	Paving and Asphalt
19/200	Construction

(Waste Amounts Indicated by Arrow to Right→)

TABLE 14
WASTES FROM
PAPER, PRINTING AND ALLIED INDUSTRIES

Activity	Amount (M lb)
Paper Products	416.5
Wall and Building Paper	125.8
Paperboard Containers	732.3
Newspapers	141.7
Books, Periodicals, Misc. Publications	137.8
Other Printing Services	525.4
	2080.5

Source: Estimated by International Research and Technology Corporation on the basis of computer materials flows and waste generation.

ii. Sawmills and Sawmill Products

Of the annual volume of trees harvested in the forest, 57 percent is made into lumber and wood products. The remainder is used as fuel, for log exports, and in pulp wood (see Table 11).

Unused residuals from primary wood manufactures amounted to 22.44 B lb (dry) in 1967. Eventually, each unit of output from primary wood manufacturing industries generates a secondary quantity of residuals in the course of remanufacture (25 percent of primary output to secondary wood products) or when used in construction (75 percent of primary output ultimately to construction industries). Residuals generated from these activities add an additional 6.98 B lb, generally much less homogeneous and occurring in much smaller localized quantities than residues generated in primary wood manufacturing. Total wood wastes were 29.42 B lb (1967).

Primary Wood Manufacturing (SIC 24xx). In 1967, 53.6 B lb board feet of saw timber were used for all purposes (lumber, plywood). Estimates of in-mill primary residual generation range from 1.26 to 1.38 tons (wet) per 1,000 board feet.[9] Of this residual, it was estimated that use is made of 80 percent--for fuel, byproduct, pulp, or paper making. The unused residual is estimated to have a moisture content after air drying of approximately 17 percent:

53.6 B bd ft x 2520 lbs/1000 bd ft = 135 B lb (wet)
x 0.20 (fraction unused) x 0.83 (dry content) = 22.44 B lb.

The amount of residuals for which a use was found varied considerably. A report from Oregon quoted 80 percent re-use, and a 1970 Washington mill survey calculated that 94 percent of wood residues and 79 percent of bark residues were utilized as by-products (including pulp and paper) or for fuel. Estimates from other areas were usually smaller, but it was found to be very dependent on the size and type of operation. Particle board and plywood manufacturers use residuals as fuel to produce steam needed in their manufacturing processes. Plywood peeler cores go to a pulp mill where they are chipped and pulped.

Increased restrictions on burning prevent many waste generators, from sawmill to remanufacture, from disposing of their waste by burning. The most economical method of disposal of residuals often becomes sending them to the pulp mill. There is a strong industry trend toward better use of wood residuals, which by all estimations are expected to decrease greatly in the near future.

Secondary Wood Products (SIC 243x - 25xx). In secondary wood manufacture, additional residuals are generated in cutting of dimension lumber and the manufacture of furniture, hardwood flooring and wood products. Wood manufacturers lose as much as 60 percent of their input to chips, shavings, sawdust, and sander dust. Although wood product manufacturers do not have as severe a bark disposal problem as do primary wood manufacturers, their operations (and wastes) are smaller and the wastes are less marketable. Wastes in 1967 totaled 4395 M lb (dry) for these sectors.

Construction (SIC 15xx - 17xx). The majority of sawmill outputs eventually is used in construction activities, where waste generation rates average roughly 6-7 percent of input, higher or lower depending on construction type, location, type of wood (lumber, plywood, mill work, etc.), and size of construction activity.

Because residual rates are so high for forest products industries, it is natural for these industries to locate close to their sources of raw materials and save the expense of transporting considerable unwanted material to places of processing. Pulp mill and sawmill wastes are located near forests, predominantly the Northwest and South Atlantic States. Wood remanufacture (dimension lumber and furniture) and paper producers, often being one step further removed from the raw material sources, are somewhat more diffuse.

The distribution of industrial wood wastes given in the attached Appendix D shows three OBE areas in Washington/Oregon each producing more than 1 B lb wood wastes annually, with other high waste regions including certain OBE areas in North Carolina, Louisiana, Mississippi and Tennessee.

The distribution of wastes projected onward to 1990 show reasonably stable sources of supply in primary wood products and in pulp production.

c. Textiles and Fabric Wastes (SIC 22xx - 23xx)

In 1967, total U.S. consumption of cotton, wool, silk, rayon, and other synthetic fibers was 9081 M lb. By 1968, this figure had reached 9781 M lb, an increase of 7.7 percent.[10] This includes total fiber consumption in carpets, apparel, upholstery, and other uses. Unused residuals in 1967 totaled about 550 M lb, or 6.0 percent of the total fiber consumption. In addition to these unused residuals, about 400-500 M lb of clippings and similar materials were recycled, used as stuffing, in felt making or in other by-products, sold to paper and pulp mills, or reused in some manner. Total process waste generated in the industry totaled 581 M lb, including paper backing and some plastic and rubber material waste.

Typically, the production of natural fibers generates only minute quantities of unusable waste, because almost any residual can be recycled. Residuals from the manufacture of synthetic fibers (including rayon and acetate) are included in the plastics sectors. Neither in the production of natural or synthetic fibers nor in their weaving into broad and narrow fabrics is appreciable waste produced. Industry estimates were the order of one-tenth of 1 percent (.001).

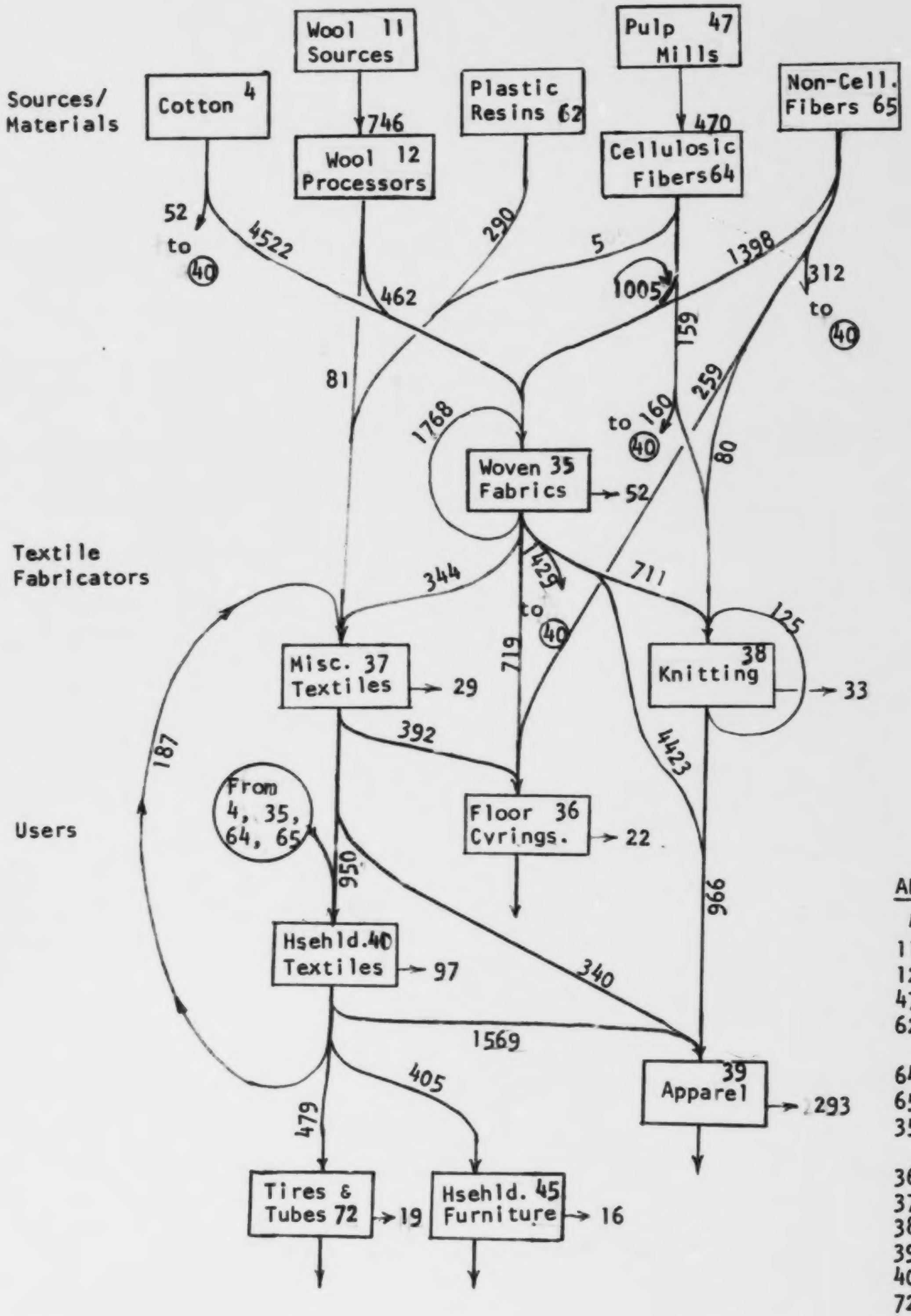
The biggest waste producer is the manufacture and remanufacture of textile products: in tires, apparel, car and furniture upholstering, carpets and rugs, and in cloth piece goods.

The apparel industry has a considerable problem with generation and reuse of cloth residuals. Primary fabric trimmings usually amount to 10-11 percent of fabric input, though manufacturers in some places have been successful in reducing this amount by computer drawn pattern layouts. Although loss per cutting operation is somewhat lower, enough fabric undergoes a remanufacturing process before final form to bring the total average residuals to the 10-11 percent listed above. Of this primary residual, about half is sold for reuse, and the remainder is either dumped or burned.

Contamination is in large responsible for the inability to reuse more of this fabric residual. Fabric of mixed fiber composition (natural and synthetic) can be reused only for stuffing or other use which depends solely on fiber bulk. Fiber separation for recycling is as yet uneconomical. Recycling purely synthetic fiber trimmings is not yet economical either, although the industry is making progress in this direction.

FIGURE 3

TEXTILE AND TEXTILE PRODUCTS
MAJOR MATERIALS FLOWS AND WASTES
(M Lb. - 1967)



ALMON NUMBERS

4	Cotton
11	Wool Sources
12	Wool Processors
47	Pulp Mills
62	Plastic Materials and Resins
64	Cellulosic Fibers
65	Non-Cellulosic Fibers
35	Broad & Narrow Woven Fabrics
36	Floor Coverings
37	Misc. Textiles
38	Knitting
39	Apparel
40	Household Textiles
72	Tires and Tubes
45	Household Furniture

(Waste Amounts Indicated by Arrow to Right →)

In the case of carpet manufacture and rubber-coated fabric, scraps are impregnated with latex, which makes them worthless from a recycling point of view. They are usually dumped or burned, though the linear dimensions of carpets make their waste generation rate smaller than that of apparel manufacture.

Future trends indicate a rapidly increasing use of synthetic fibers. By 1974, output of synthetics is expected to be double that of natural fibers.

Residues generated from textile and apparel manufacturing industries are concentrated most in the Middle and South Atlantic States, and are expected to become even more concentrated in the future. The South Atlantic States of North and South Carolina and Georgia now account for over half the total textile mill production. In the apparel and textile products industry, also, the South and South Atlantic regions are expected to show the fastest growth.

d. Non-Fiber Synthetic Materials

i. Plastics (SIC 282x, 3079)

Estimates of unusable residuals generated in the plastics product industry varied from between 2 percent and 5 percent of total plastics input. Waste generation rates for the manufacture of plastic materials and resins were about 1.1 percent. Because of concern within the industry for the diseconomies incurred by this waste, the rapid growth rate of the industry itself (and therefore its residuals) and public concern for plastics pollution, the tendency was to side with the lower estimates, conservative in 1967, but expected to be a reasonable estimate of the industry's process waste problem in the future.

The industry consists basically of two sections: a manufacturer (SIC 2821) of plastic materials and resins from chemical components, and various users of these resins who manufacture finished plastic products (see Table 15).

The waste generation rate for the manufacture of finished plastic products is approximately 2.2 percent, implying a total plastics waste (1967) of (.011 + .022) 14,040 = 460 M lb[11] and an estimated (.011 + .022) 20,000 = 660 M lb in 1971. An equal amount of residual is generated, which is recycled (in the case of thermoplastics only) or sold for polymer uses which require lower material specifications. (Figure 4 depicts major materials flows of plastics and rubber among waste-generating economic activity sectors.)

TABLE 15

PLASTICS CONSUMPTION (1967)

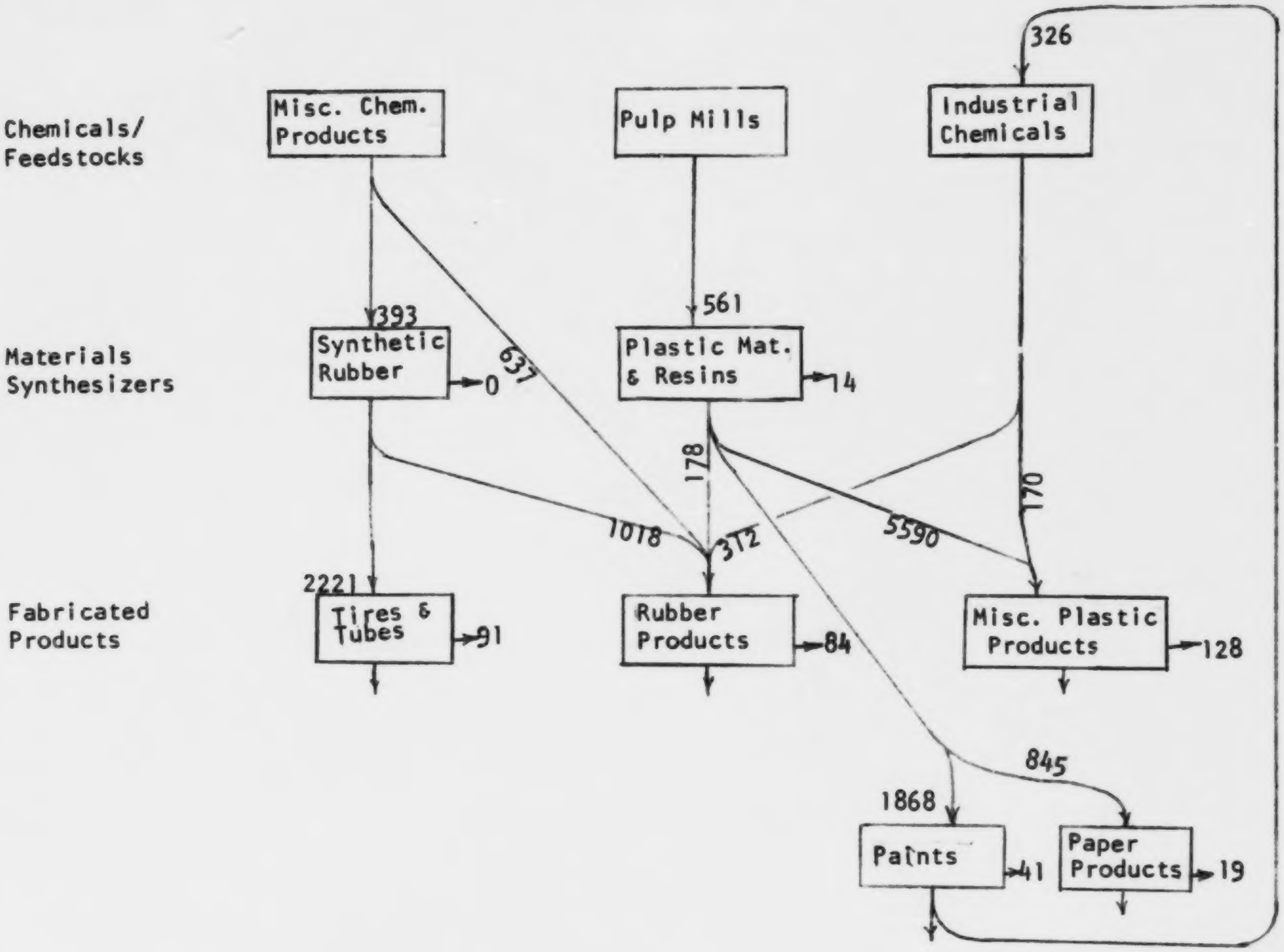
Adhesives	923.3 M lb
Laminating	207.5 M lb
Molding and Extrusion	5587.9 M lb
Paper and Textile Treatment	870.1 M lb
Protective Coatings	1124.8 M lb
Sheets, Film, Rods, Tubes	2302.6 M lb
Other	3023.8 M lb
	14040.0 M lb

Note: It is difficult to establish the exact relationship between the estimate calculated through the materials flow analysis and this estimate because of the diffuse nature of plastics uses. Only 56 percent of the resins are finished in SIC Sector 3079. At the level of aggregation in which the model was developed "plastics materials and resins" (SIC 2821) was buried in "chemicals" (SIC 28) and eventually in "miscellaneous manufacturers." Other uses of plastics materials and resins (i.e., not in 3079) generated plastic waste which was dispersed among the process waste of minor users of plastics.

Source: Stanford Research Institute, Chemical Economics Handbook, Menlo Park, California, 1967, p. 581.0050.

FIGURE 4

MAJOR MATERIALS FLOWS AND WASTE
RUBBER AND PLASTICS
(M Lb. - 1967)



ALMON NUMBERS

62	Plastic Material and Resins
47	Pulp Mills
49	Paper Products
63	Synthetic Rubber
72	Tires and Tubes
73	Rubber Products
74	Misc. Plastic Products
55	Industrial Chemicals

(Waste Amounts Indicated by Arrow to Right →)

ii. Rubber Products (SIC 30xx)

Rubber compound wastes generated in the manufacture of all rubber products totaled 260 M lb in 1967, or 4.93 percent of the 5270 M lb total rubber consumed (3643 M lb synthetic, 1092 M lb natural, 534 M lb reclaimed).[12] (See Table 16.) Of this, 40 percent was generated in the rubber tire industries, which consumed 70 percent of rubber materials. The remainder, 155 M lb, was generated as a result of manufacturing hose, belting, footwear, sponge, and miscellaneous rubber products. All rubber product industries produced an estimated 10.7 B lb of products, indicating a high degree of mixing with metal, textile, chemicals, and other materials. The usual non-homogeneity of rubber scraps prevented their being reclaimed.

TABLE 16

RUBBER PRODUCTION, CONSUMPTION AND WASTE (1967)
(Million Pounds)

	Synthetic	Natural	Reclaimed	Total	Waste
Tires	2221.	750.	306.	3277	104.8
Wire Cable	81.	2.2	0.2	83.4	3.5
Footwear	52.2	36.0	1.8	90.0	22.0
Hose Belts Foam & Sponge Other Mech Goods	1293	304	226	1818	130.2
	3643	1092.2	534.2	5269.4	259.5
Exports	680				
Production	4323				

Source: Current Industrial Reports, Rubber: Supply and Distribution for the United States, U.S. Department of Commerce, Bureau of the Census, Industry Division, Washington, D.C.

Because of high volume, large item manufacturing, the tire industry has been able to keep rubber wastes down to a minimum, about 3.2 percent as compared with 7.2 percent for non-tire items.

Compound wastes in tires are unusable largely because of contamination from fabric or steel banding, which makes reclaim uneconomical. Rubber quality standards in tires also prevent broader use of reclaimed rubber.

Reclaimed rubber accounted for 10.3 percent of the new rubber supply in 1967, after supplying more than 18 percent as late as 1958.

Wastes in other rubber product manufacture are due to fabric or metal inhomogeneities and to the type of article being produced. Rubber-coated fabric trimmings are currently not being reclaimed extensively.

Most unsalvaged rubber compound scraps leave the plant mixed with wood, paper, metal, and textile plant trash. Disposal by incineration is an especially severe problem for rubber wastes because of large quantities of smoke and unpleasant odor. Those wastes not finding their way back into the reclaim stream are disposed of as landfill.

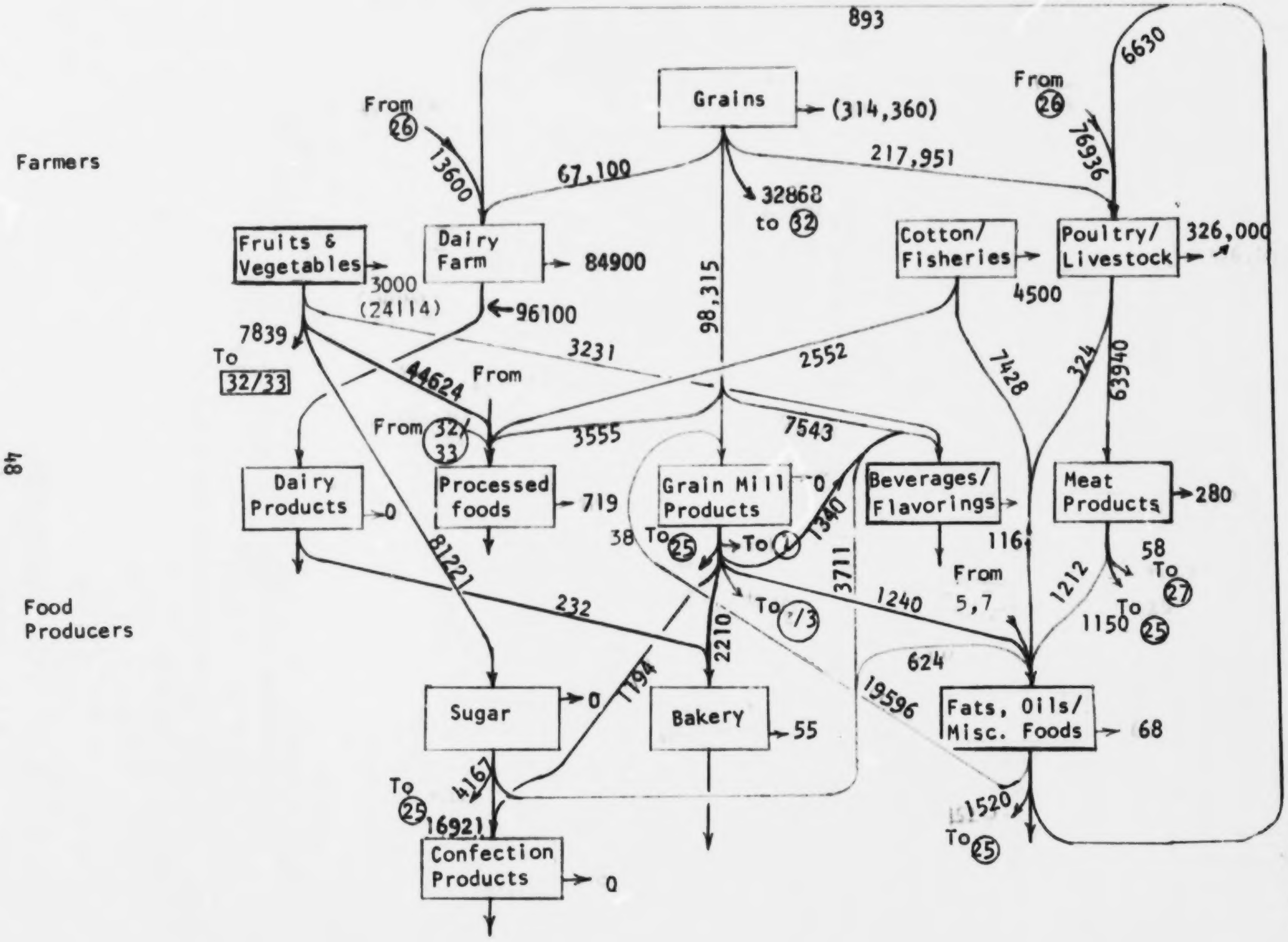
Rubber product manufacturers are not distributed uniformly nationwide, and a much larger than proportionate share of rubber waste is likely to be generated in the Midwestern states of Ohio, Indiana, Illinois, and Michigan (see attached Appendix D, which shows the approximate rubber and plastic wasteloads by OBE sector). In the case of rubber products, however, discarded products (e.g., used tires) are much larger in volume than fabrication waste (probably by a factor of nearly 20). The distribution of discarded rubber tires is, in general, a much more important consideration for purposes of general waste management than the location of rubber product fabricators, and is, of course, much more uniform nationally.

e. Food Processing (SIC 20xx)

Food processing residuals, because of their nutritional value even in a degraded form, have been used very efficiently as animal feeds and fertilizers. Total dry weight of unused wastes from grain milling, fruits, vegetables, meat, seafood, and sugar are estimated at 1430 M lb (1967), and are generated almost exclusively in fruit and vegetable canning, and meat product sectors. Unusable dry wastes amounted to only .32 percent of the food-containing materials sold from agricultural sectors (SIC 01xx and 07xx) to food processors (SIC 20xx), which in 1967 amounted to 450.3 B lb (wet weight). (This input figure does not double count for doubly-processed materials (e.g., grain to flour to bread), nor does it account for direct sales to fresh market, or grain sales directly from grain growers to livestock and poultry producers.

FIGURE 5

AGRICULTURE AND FOODS
(Dry Residue →; All quantities, M Lb.; Field Residue in Parentheses)



ALMON NUMBERS

1	Dairy Farm
2/3	Poultry/Livestock
4/8	Cotton/Fisheries
5	Grains
7	Fruit and Vegetables
23	Meat Products
24	Dairy Farm Products
25	Processed Foods
26	Grain Mill Products
27	Bakery
28	Sugar
29	Confectionary Prods.
30/ 31	Alcoholic Beverages/ Soft Drinks, Flavorings
32/ 33	Fats and Oils/ Misc. Foods

(Waste Amounts Indicated by Arrow to Right →)

Wastes include all process wastes from all food processing sectors (SIC 20xx).) Figure 5 displays major flows of agricultural commodities through food processing sectors.

i. Grains

Processing of grains generates no unused residuals, except in canned and frozen vegetables (corn). All materials remaining after manufacture of primary products are used as animal feeds. Most (about 70 percent) grains are supplied to livestock directly, without ever entering the food processing sectors. Of the remainder, most are sold to various subsectors of grain mill products (98315 M lb) which then channels its primary residual into the subsector for prepared animal feeds. The other large food processing market for grains is vegetable oil producers (32868 M lb in 1967), which then transfers oil-depleted meal to animal feeds. The remainder is sold to the alcoholic beverage industry (7453 M lb), which in turn sells its dried malt, barley, hops, and yeast as animal feed. A relatively small amount (3555 M lb) was sold to the canned and frozen food industry, and generates some waste. Almost all of the grain mill products which are consumed by humans are either in milled or oil form.

ii. Meat and Poultry Slaughter (SIC 201x)

Slaughter wastes are of two types, paunch material and animal tissue, which are generally handled separately. Residual animal tissue (blood, bone, feathers, hides, and flesh) can be used entirely as by-products and are usually not wasted. Usual uses are meat by-products, dog and cat food, fats and greases, and fertilizer. Hides are sold to tanning and leather manufacturers, and there is a significant non-leather waste in that area. As with virtually every industry, the ability to find an economic use for residuals is dependent on plant size (therefore, quantity of waste) and availability of markets. There is a variation in animal tissue disposal methods, and residuals from meat packing plants far from by-product markets are sometimes treated as waste: dumped or burned.

Paunch manure is waste. Table 17 estimates paunch wastes for 1967. This (wet) material is usually disposed of at landfill sites or by burning, although some is allowed to decompose in ponds and/or is used as fertilizer.

In quantity, though, slaughter residuals from each animal equals only about one day's manure generation for that animal and are therefore very small in comparison to feedlot manure (and bedding wastes).

TABLE 17

PAUNCH MANURE GENERATED FROM ANIMAL SLAUGHTER

Animal	Typical Weight at Slaughter (Lbs)	Paunch (Wet) Lbs/Animal	Dry w/c	Animals Slaughtered M (1967)	Total Waste (M lb)
Cattle	1100	75	.007	32.4	218
Horses	750	45	.006	.05	.24
Swine	250	7	.002	74.58	38.2
Sheep	100	3	.003	11.56	
Chickens	4-5	.25	.012	2592.	112

Note: Because "weight at slaughter" is not the mathematical "mean weight," waste total approximate waste calculated on the basis of numbers in this table.

Sources: Industrial Solid Waste Survey, Oregon: 1970, Oregon State Board of Health, funded by grant 605-UI-00014, awarded by USPHS; Agricultural Statistics, 1968, U.S. Department of Agriculture, Government Printing Office, 1968.

Quite naturally, the geographical distribution of slaughterhouse wastes corresponds roughly to distribution of major feed grains and cattle and hog feedlots.

iii. Canned and Frozen Fruits and Vegetables (SIC 203x)

Although primary residuals from processing fruits and vegetables total 36 percent of input quantities (averaged over all products), dry combustible solids content of unused residuals are only slightly over 1.3 percent. Largest by-product use of primary residuals is for animal feeds. Where a nearby market is available, the remainder is used as fertilizer, although in most cases the expense of handling does not justify the cost. Both primary and ultimate residual fractions are dependent considerably on process used and vary from vegetable to vegetable. In processing citrus fruits, for example, the primary waste is 40-44 percent, but it can all be used in animal feed, even though there is some waste disposal, as now practiced. Tomatoes, on the other hand, have

10 percent primary residues which cannot be used at all, even in products such as tomato juice and sauce.

Table 18 summarizes waste generation practices in fruit and vegetable processing.

As a rule, the reason that ultimate residuals cannot be used is contamination, handling costs, or costs of converting to a saleable product. Contamination can occur because of pesticides (which remain concentrated in parts of the plants), in plant processes or post-process mixing with other materials. Because of high water use in the industry, wastes are often generated in a slurry form, which makes sewering or ponds the most economical means of disposal. Most wastes are disposed of as spread or fill.

The Western and Southern regions are the largest suppliers of processed fruits and vegetables, and together account for about 40 percent of the total value of products produced in that sector. It is expected that in the future production will become more diffuse, including an increasing fraction which will be produced and processed in Mexico.

iv. Seafood and Fish Products (parts of SIC 20xx)

Only in two isolated cases is any appreciable combustible process waste generated by the fishing industry. Any residual remaining after processing for human consumption is made into oils, animal (cat) food, fish and bone meal, bait, or fertilizer. Non-combustible wastes generated include fish scales (for which there is no use currently), high-fluorine-content bone residues, and some shellfish residues. Of the latter, some are disposed of by landfill and some are returned to the water.

There are, however, two special cases in which the industry has had a CSW disposal problem. In Alaska, due largely to an absence of markets for fish by-products, some appreciable fraction of the organic residuals are disposed of as waste. Second, menhaden fishermen and coastal processors have created some problems when they flushed their boats and processing plants. The fraction of fish throughout disposed of uneconomically on or near land is extremely small, however (<.001).

f. Miscellaneous Manufacturing

i. Leather Tanning and Leather Products (SIC 31)

Every 100 pounds of raw hides entering the leather tannery generates 25 pounds of hair, flesh scrapings, and other non-leather

TABLE 18

RESIDUALS FROM PROCESSED FRUITS AND VEGETABLES (M lb)

Product	Input	Residual	Used	Waste W	W/C
Asparagus	240	84	38	46	.038
Lima Beans	240	38	20	18	.015
Snap Beans	1260	260	128	132	.021
Beet	540	180	36	144	.053
Cabbage	460	152	12	140	.060
Carrot	560	280	200	80	.028
Corn	4960	3240	3160	80	.007
Greens, Spinach	480	66	48	18	.008
Mushroom	134	65	0	64	.096
Pea	1160	148	98	50	.009
White Potato	7140	2340	2080	260	.007
Squash (Pumpkin)	440	110	50	60	.026
Tomato	13940	1040	240	800	.014
Misc. Veg.	2440	540	220	320	.026
Apple	2100	580	400	180	.018
Apricot	240	32	18	14	.027
Berry	400	28	2	26	.013
Cherry	380	52	8	44	.023
Citrus	15600	6160	6006	154	.002
Misc. Fruit	300	72	20	52	.036
Olive	170	22	20	2	.002
Peach	2200	580	188	392	.068
Pear	820	240	72	168	.043
Pineapple	1800	800	720	80	.013
Plum/Prune	54	14	0	14	.052
Dry Bean	460	14	4	10	.004
Pickle	1120	82	0	82	.015

W/C = Waste Coefficient = (dry unused combustible waste)/(input, "as is")

Source: Solid Waste Management in the Food Processing Industry, by National Canners Association for U.S. Environmental Protection Agency, under contract number PH 86-68-138, 1971.

residuals. In 1967, this amounted to 80.1 M lb of materials in a total leather (cattle, calf, swine, deer, etc.) throughput of 320.4 M lb.

Presently, these materials are strained from solution and burned, landfilled, or sewered.

Manufacturers of leather products from stock leather generate virtually no unused residuals, although clippings and scraps often amount to 40 percent of leather input. The scraps are sold to by-product manufacturers.

Because not every product from the leather product industry is 100 percent leather, other process waste is generated by this grouping of economic activities. In 1967 these were calculated to be 37 M lb, for a total process waste of 117 M lb. Plant trash from the industry was estimated to be 683 M lb. Therefore, process waste comprises less than 15 percent of the total waste generated in the industry and, being liquid-borne, contaminated, not particularly homogeneous, and a rather small quantity, is not an appreciable resource.

ii. Tobacco Products (SIC 21)

Largely because of the high cost of purchased tobacco ($75 per cwt) and the variety of tobacco by-products which can use virtually all tobacco residuals, tobacco wastes are limited to contaminants, fines, lints, and similar unacceptable material.

An industry estimate of 4 pounds waste per 1,000 pounds of tobacco input (.004) would result in 11 M lb annual unused residual. Other associated process wastes generated by the industry (cellophane, paperboard containers, paper, etc.) were 15 M lb, for a total process waste of 26 M lb compared to a plant trash total of 176 M lb. Again, the process methods are responsible for the industry's solid waste problem only to the smallest degree.

All residues (process waste and plant trash) are usually mixed together with floor sweepings, air conditioner filter cleanings, and the small quantities of tobacco wastes, and rarely appear in a condition homogeneous enough to justify separation and/or use.

3. Refuse and Sewage/Urban-Generated Wastes

This section is divided into five subsections and covers all waste typically disposed of "after-use." It is the remains of those combustible materials which, having been manufactured, marketed, and consumed are now used and discarded. Table 19 lists sources and quantities of the five waste flows treated in this section.

TABLE 19

REFUSE AND SEWAGE SOURCES AND QUANTITIES

Sources	Quantities (B lb, 1970)
Household and Municipal Waste	168.4
Sewage Sludge	25.4
Commercial and Institutional Waste	60.0
Manufacturing Sectors Plant Trash	23.6
Demolition Residues	7.7
Total	284.9

Source: Estimated by International Research and Technology Corporation, January-March, 1972, based on analysis described in Appendix C.

Household and municipal wastes, sewage sludge, and commercial and institutional waste were analyzed in detail on the basis of SMSAs, and extrapolated to encompass wastes generated in the entire United States--both in and out of SMSAs. Because SMSAs are localized population centers, they are similarly waste-generation centers, and an analysis based on this description is more meaningful in terms of both waste problem and resource recovery potential. In 1970, 68.6 percent of the U.S. population lived in the 243 SMSAs defined by the Bureau of the Census. These SMSAs covered 10.96 percent of the geographic area, indicating a waste concentration more than 6.25 times as high as in the United States as a whole, and more than 17.7 times as high as those areas not in SMSAs. (Waste generation rates for most sources of refuse are higher in SMSAs than out of SMSAs, implying that the relative waste concentration is even greater than the population concentration.)

Although each of these subsectors listed above generates its own characteristic composition of waste, they all have in common a problem of non-homogeneity.

a. Household and Municipal Wastes

The category of household and municipal wastes as defined for purposes of this study includes refuse generated in households, refuse from streets and alleys, trees, landscaping, parks, beaches and catch basins. Wastes were calculated on a per capita basis, and regionally on an SMSA basis. Projections were based on three factors:

(1) changing population

(2) changing volume of per capita CSW generation
(3) changing composition of waste.

In most regions of the United States, municipal and household generated wastes are the most important waste problem, because of the large quantities in which they are produced, because of their distribution, and because of the costs that must be paid in order to collect, process, and dispose of them in as environmentally sound a manner as possible.

Total per capita solid waste generation (combustible and non-combustible) has been estimated by one source to be as high as 5.3 lbs per day, and expected to increase to about 8.0 lbs per day in 1980.[13] The combustible waste projections in this report are based on the more detailed and disaggregated EPA data assembled for the _1968 National Survey of Community Solid Waste Practices_,[14] the most comprehensive source currently available. Table 20 gives the current and projected levels of _dry combustible municipal waste_, divided into natural and synthetic portions.

TABLE 20

COMPOSITION OF COMBUSTIBLE HOUSEHOLD AND MUNICIPAL WASTES
(Lb per Capita per Day Dry Weight)

	Natural Materials	Synthetic Materials	Total
1970	2.17	.08	2.25
1980	2.49	.22	2.71
1990	2.76	.63	3.39

Sources: _1968 National Survey of Community Solid Waste Practices_, Auton J. Muhlich, A.J. Klee and P.W. Britton, U.S. Department of Health, Education, and Welfare, Cincinnati, 1968; "An Analysis of Domestic Refuse, Santa Clara County, California, 1967," published by Office of Science and Technology, Washington, 1968.

Per capita figures were used to tabulate total municipal waste generated in each of the 243 Standard Metropolitan Statistical Areas (SMSAs) using census figures and projections.[15] The results of these calculations and projections are contained in detail in the data bank. Table 21 summarizes total municipal CSW, municipal CSW generated in SMSAs, and projected national totals for 1980 and 1990.

TABLE 21

HOUSEHOLD AND MUNICIPAL WASTE TOTALS:
SMSA/US; 1970/PROJECTED

	In SMSA	Total U.S.
1970	(68.6%) 115.6	168.4
1980	(75.1%) 169.0	225.0
1990	(80.8%) 254.3	315.2

b. Sewage Sludge

Sewage solids are generated in municipal regions at an average daily rate of 0.5 to 0.6 pounds per person.[16] Sewage treatment plants capture, concentrate and destroy varying percentages of this solids load depending upon the degree and type of treatment employed. The 1968 National Survey of Community Solid Waste Practices indicated that the average daily generation rate of "sewage treatment plant solids and pumping station cleanings" requiring disposal as sludge was 0.34 pounds (dry) per capita.[17] Although this figure represents an average over many different treatment plants employing different practices, it is biased toward sewage plants that apply both primary and secondary treatment. (The percentage of the population discharging raw sewage has dropped from 22 percent in 1957 to less than 7 percent by 1968 and is expected to continue declining.)[18] The projected sewage sludge generation rates and totals, shown in Table 22, are based on the figure 0.34 pounds (dry) per capita-day in 1970.

Currently, most (95 percent) sewage sludge is settled, concentrated and dumped in lagoons. About 5 percent is concentrated and burned.

c. Commercial and Institutional Wastes

Waste generated in commercial and institutional sectors were also calculated on the basis of SMSAs, although the calculations pertaining to generation rates, composition and projections required a more detailed analysis than a strict per capita basis would yield.[19] Appendix B contains a description of the methodology. Table 23 gives 1970 and projected total wastes from each sector analyzed.

Combustible waste generated in the retail and wholesale trade sectors was tied to the level of dollar sales, and future wasteloads

TABLE 22

SEWAGE SLUDGE

	Per Capita Daily Generation Rate (lb) Dry	Total SMSA (B lb)	Total U.S. (B lb)
1970	0.34	17.4	25.4
1980	0.37	23.0	30.7
1990	0.39	29.4	36.3

Sources: Burd, R.S. "A Study of Sludge Handling and Disposal," U.S. Department of the Interior, Federal Water Pollution Control Administration, Office of Research and Development, Publication No. WP-20-4, May 1968; 1968 National Survey of Community Solid Waste Practices, U.S. Department of Health, Education, and Welfare, Cincinnati, 1968.

TABLE 23

TOTAL U.S. COMMERCIAL AND INSTITUTIONAL CSW LOADS

	1970 (B lb)	1980 (B lb)	1990 (B lb)
Retail and Wholesale	13.1	17.5	21.3
Schools	12.0	12.6	11.6
General Office	12.3	14.8	14.0
Hospital	4.9	6.8	8.2
Restaurant	19.8	27.0	38.7
Totals	60.1	78.6	94.8

Source: Estimates based on International Research and Technology Corporation staff analysis and projections. (See Appendix B, for description of methodology.)

were projected on the basis of expected levels of sales for 1980 and 1990. This CSW is almost exclusively packaging waste, including corrugated paper and some dunnage. Since the nature of packing materials is changing rapidly, the projected waste level was corrected for expected changes in type of packaging, and increasing use of reusable containers. Table 24 gives the waste-generation rates on which the wholesale and retail trade wasteloads were based.

Retail and wholesale trade wastes are concentrated most in urban areas, and though the wastes are usually collected by private contractors, they undergo disposal by methods similiar to those of other urban generated CSW.

TABLE 24

RETAIL AND WHOLESALE TRADE WASTE GENERATION
(Lbs per $11.90 of Sales)

	Total Combustible	Natural Materials	Synthetic Materials
1970	1.00	.98	.02
1980	.903	.88	.023
1990	.818	.792	.026

Source: Estimate based on International Research and Technology Corporation staff calculations. (Appendix B, contains a complete description of methodology and sources used.)

Waste generation in elementary and secondary schools was calculated on the basis of waste per student multiplied by the average daily attendance. Future levels were based on projected school-age population.

Waste generation in the restaurant sectors is expected to show the most dramatic growth between 1970 and 1990, largely because of projected increases in per capita restaurant sales. In addition to an increasing number of meals to be supplied by the restaurant sector, it was also projected that the generation of CSW per meal would rise about 20 percent in the 20-year period 1970-1990. The composition of CSW from restaurants is largely packaging wastes and food scraps, generated in meal preparation and uneaten portions of meals.

d. Manufacturing Plant Trash

Manufacturing plant trash, which does not include process-generated waste or administrative/office wastes totaled 23.5 B lb in 1967, with the composition (combustible only) shown in Table 25.

Between 85-90% of plant trash is combustible. Appendix C lists a sector by sector breakdown of plant trash generation.

Plant trash includes discarded packaging materials, paper, paperboard, textile and plastic, broken crates, cartons, shipping pallets, dunnage, cafeteria and food wastes and other wastes (non-office and non-process) generated in day-to-day activities.

TABLE 25

TOTAL COMBUSTIBLE MANUFACTURING PLANT TRASH

	Amount (B lb)	% of Combustible
Wood	9.5	40.4
Paper	13.3	56.6
Textile	0.3	1.3
Rubber & Plastic	0.4	1.7
	23.5	100.0

Sources: Cummins, Rodney L., A Study of Solid Waste Management in the Tobacco Products Industry, U.S. Department of Health, Education, and Welfare, Public Health Service, 1970; Culham, W.B., G.F. Beachler, B.B. Bailey, R. Sorenson, Solid Waste Management Practices: Oregon State Report 1969, Solid Waste Section, Oregon State Board of Health, Portland, Oregon.

For purposes of disposal, all plant wastes are generally disposed of in common containers, though process waste may or may not be separate depending on the industry.

Relatively little salvage from these wastes takes place because of the inhomogeneity of wastes, although some salvage of corrugated paper and wood does occur.

Trends in the future point to a shift in composition of wastes, due primarily to trends in packaging materials towards higher plastics use and reusable containers. Per capita generation (production line employee) is not expected to decrease, however, because of (1) resistance (economic) to waste separation and salvage, and (2) increased throughput (productivity) bringing a commensurate increase in materials handling.

Plant trash is commonly disposed of in a manner similar to other urban generated wastes, though the composition is somewhat different. Landfill is common, and since manufacturing industries tend to locate nearer the peripheries of urban areas, their disposal problem is not as acute as is that of offices, commercial areas and high-density urban areas.

Expected waste loads for 1980 and 1990 are (for each sector) given in Appendix C and summarized in Table 26.

TABLE 26

PROJECTED PLANT TRASH WASTE LOADS

	1980		1990	
	Amount (B lb)	% of Combustible	Amount (B lb)	% of Combustible
Wood	14.5	36.5	17.4	33.2
Paper	23.5	59.3	31.7	60.2
Textile	0.6	1.5	0.8	1.5
Rubber & Plastic	1.1	2.7	2.7	5.1
	39.7	100.0	52.8	100.0

Source: Estimates based on level of economic activity, analysis by International Research and Technology Corporation staff. (Appendix C contains a description of methodology used.)

e. Demolition

Total nationwide wastes from demolition activities (SIC 1795) totaled 38.7 B lb in 1967, of which a maximum of 20 percent by weight is combustible, implying a total combustible waste of 7.7 B lb.[20] Although in absolute terms this represents a considerable source of combustible materials, in fact it is so mixed with non-combustible (stucco, masonry, wire, etc.) that salvage has become less economical with rising labor costs. Currently almost all waste is landfilled or dumped. On-site incineration has been severely restricted by burning codes.

Projections of CSW from demolition activities for 1980 and 1990 are shown in Table 27.

TABLE 27

COMBUSTIBLE DEMOLITION WASTES

Year	Amount
1967	7.7 B lb
1980	8.7 B lb
1990	10.0 B lb

Source: Technical-Economic Study of Solid Waste Disposal Needs and Practices, by Combustion Engineering, Inc., Windsor, Conn., for Bureau of Solid Waste Management, U.S. Department of Health, Education, and Welfare, Public Health Service Publication No. 1886, p. II-45.

F. SUMMARY OF PROJECTIONS AND HEAT CONTENT

1. Agricultural and Industrial Wastes

For purposes of display, the 131 Almon buying sectors (listed in Appendix A), have been divided into ten groups whose members produce similar waste. These are:

Title	Almon Sectors
Agriculture and Forestry	1-18
Food Processing	23-34
Textiles	11-12, 35-40
Wood	41-46
Paper	47-54
Leather	75-77
Rubber	72-73
Plastics	62-74
Construction	19, 201-206
Misc. Manufacturing	remaining sectors

In addition to projecting future waste loads on the basis of two population growth-rates, an added variable of high or low economic activity was included, to give a total of four projection scenarios. The two extremes, high population growth-rate--high economic activity, and low population growth-rate--low economic activity, were chosen in order to evaluate the sensitivity of the waste loads with respect to these variables. Table 28 lists a range of projected waste loads (and heat content of those wastes). These two projection levels determine the upper and lower limits of that range. (A more detailed description is given in Appendix A).

So far, little has been said about the potential for heat recovery from CSW streams. Estimates of total heat content accompanied all waste flows for agricultural and industrial waste streams and are summarized in Table 28, which was derived from the Almon model.

2. Refuse and Sewage/Urban-Generated Wastes

Wasteloads generated by final-users described in Chapter III were estimated by extrapolation of trends in population and economic growth, and are summarized in Table 29, for base years and projected levels for 1980 and 1990.

Since estimates are already in dry-weight content, the total heat content of waste generated by these sources can be estimated

TABLE 28

Agricultural and Industrial Wastes: Projections and Heat Content 1967/1980/1990

Category of Economic Activity	Combustible Wastes M lb.	Heat Content Btu, billions
1967		
Agriculture and Forestry	465,200.0	3,506,212.4
Food Processing	1,428.3	11,937.1
Textiles	581.3	5,169.1
Wood	31,613.2	316,164.4
Paper	22,788.8	225,198.9
Leather	117.7	1,209.5
Rubber	175.0	2,180.9
Plastics	142.5	1,706.7
Construction	2,599.8	25,852.2
Misc. Manufacturing	2,420.4	25,392.9
TOTAL	527,203.5	4,121,022.6
1980		
Agriculture and Forestry	682,514.9--711,825.1	5,142,767.8--5,265,446.9
Food Processing	2,197.4-- 2,259.7	18,199.9-- 18,741.9
Textiles	951.9-- 1,022.4	8,469.1-- 9,086.0
Wood	25,518.0-- 27,927.0	255,203.1-- 279,300.0
Paper	18,174.0-- 19,598.0	179,569.0-- 193,671.0
Leather	118.8-- 177.0	1,224.1-- 1,820.0
Rubber	243.6-- 264.1	3,033.6-- 3,288.8
Plastics	286.4-- 313.4	3,440.0-- 3,765.6
Construction	4,109.3-- 4,456.6	40,845.2-- 44,305.4
Misc. Manufacturing	3,903.0-- 4,260.3	40,959.9-- 44,726.7
Total	738,018.3--772,103.6	5,693,738.7--5,964,143.3
1990		
Agriculture and Forestry	797,280.3--898,462.0	5,968,621.4-- 6,726,096.2
Food Processing	2,415.2-- 2,630.6	20,186.3-- 22,053.6
Textiles	1,212.8-- 1,467.3	10,787.1-- 13,038.1
Wood	16,197.0-- 19,451.0	161,988.8-- 208,450.1
Paper	12,164.0-- 14,470.0	120,199.0-- 143,057.4
Leather	199.4-- 315.4	2,051.1-- 3,239.1
Rubber	314.0-- 373.1	3,908.7-- 4,643.4
Plastics	409.7-- 500.0	4,902.7-- 5,987.6
Construction	5,271.9-- 6,040.1	52,378.3-- 60,025.7
Misc. Manufacturing	5,025.2-- 5,970.8	52,737.5-- 62,678.3
Total	840,489.5--930,236.3	6,397,760.9--7,429,269.5

TABLE 29

CSW GENERATED FROM FINAL USERS: BASE YEAR AND PROJECTED LEVELS

Source of Waste	Base Year[a] (B lb)	1980 (B lb)	1990 (B lb)
Household and Municipal	168.4	225.0	315.2
Sewage Sludge	25.4	30.7	36.3
Commercial and Institutional	60.0	78.6	94.8
Plant Trash	23.6	39.7	52.8
Demolition	7.7	8.7	10.0
	285.1	382.1	509.1

[a] 1970 for 1, 2, 3; 1967 for 4, 5.

Source: Projections based on International Research and Technology Corporation staff analysis of individual waste levels.

as 1,425.5 trillion Btu for base year (using a conservative 5000 Btu/dry lb), 1,913.5 trillion Btu for 1980 and 2,545.5 trillion Btu for 1990. Although these figures are smaller than the heat content available in agricultural and industrial waste, in a real sense they are much more "available" generally because they have, of necessity, already been collected. (Collectability is a considerable barrier to resource recovery of any kind for the two largest agricultural flows: non-feedlot manure and forest residue.)

For purposes of comparison of magnitude of waste streams, Table 30 sets forth the base year flows in descending order of magnitude.

Agricultural and Forest residues are by far the largest amount of combustible solid waste in any category. Approximately 10 percent of the total CSW is generated in feedlots and other animal concentrations, as shown in Table 2. With the exception of fruit tree prunings (approximately 0.3 percent of total CSW), the remainder do not pose a disposal problem because they are not concentrated.

Restrictions on burning can have the added effect of driving forest residuals into a resource market, i.e., to be shipped for pulp mills.

TABLE 30

TOTAL COMBUSTIBLE SOLID RESIDUES
(Base Year[a] - B lb Dry)

Source	Amount	% of Total
Agriculture and Forestry[b]	468.0	57.60
Household and Municipal	168.4	20.73
Commercial and Institutional	60.0	7.38
Wood Industry Wastes	31.6	3.89
Sewage Sludge	25.4	3.13
Plant Trash	23.6	2.90
Pulp, Paper and Allied Industries	22.8	2.81
Demolition	7.7	0.95
Construction	2.6	0.32
Food Processing	1.4	0.17
All Other Manufacturing	1.0	0.12
Total	812.5	100.0

[a] 1970 is base year for: Household and Municipal, Commercial and Institutional, Sewage Sludge; the remainder have base year 1967.

[b] Includes forest residues, animal manure and fruit tree prunings only.

Source: Compendium of information generated in this report.

Although household and municipal waste, commercial and institutional waste, and plant trash are generated as a result of different activities, all are typically inhomogeneous, generated in or near urban centers, and use and adapt to equivalent disposal methods. They total more than 252 B lb annually and as a group account for 31 percent of the total solid waste generated each year. Unlike animal and forest waste, almost all of this waste is currently collected. The largest amount of combustible solid process waste generated by any one industry is due to sawmills and wood products manufacture. It consists of bark, slash, sawdust and sander dust, chips and some non-wood wastes generated in furniture manufacture (SIC 25). Although the magnitude of this flow is considerable, all visible trends within the industry point to a much increasing use of wood residuals and a consequent decrease in the quantity of residuals handled as waste. The growing number of uses for wood residuals include methods of incorporating quantities of sawdust and bark, generally the most troublesome wood wastes, into wood pulp and compacted wood waste products (particle and hardboard).

The magnitude of the wood waste problem is, as a result of these trends, becoming a much less severe problem than it has been in the past, and it can be expected that as these trends develop further, wood processing residuals will no longer be the major source of CSW that they now are.

The quantity of sewage sludge generated annually, now 25.4 B lb, is increasing more rapidly than population. Projected quantities for 1980 and 1990 reflect the fact that rising per capita generation and expansion of suburban sewer systems will increase markedly the amounts of sewage that will require treatment.

Of the 22.5 B lb of combustible residuals generated by pulp, paper and allied industries, over 2 B lb is generated in the allied industries sectors and is disposed of as waste because it cannot be salvaged. This portion is essentially municipal-type waste and is disposed of as such. The remainder, a chemical sludge from the pulp process, will be further reduced by trends described in the section on wood-related wastes.[21] Both for economic reasons associated with resource recovery in the sulfite process and because public opposition is eliminating the inexpensive dumping that has heretofore been an alternative to resource recovery, it seems certain that industrial waste generation in this sector will be reduced sharply due to these pressures alone.

Food processors, one of the most efficient users of their inputs of any industry, still generate over 1.4 B lb of process residuals each year. All other manufacturing industries generate 1 B lb process waste, or 0.12 percent of the total annual CSW. These materials are typically those residuals which would not be drawn back into the production stream because of contamination, inadequate technology for reuse, high handling costs, or lack of a local market. Process wastes occurring in small quantities are usually disposed of in the same manner as plant trash. They are not handled separately except in cases where they are water-borne or are generated in extremely large quantities, such as in sawmills, furniture mills, pulp mills and paper mills. It is generally true (with the above exceptions) that (1) primary process residuals are generated in unusually homogeneous quantities (relative to other combustible wastes) and (2) when those quantities are large enough, an economical use is found for them.

IV. ALTERNATIVE APPROACHES TO EASING SOLID WASTE PROBLEMS

A. INTRODUCTION

The federal government's opportunities to ameliorate solid waste problems can be classed in three categories: reducing the generation of wastes, improving or reducing costs of procedures for collecting and disposing of wastes, and affecting the costs of production or markets for products derived from wastes. With respect to each class, we have considered the possible governmental actions under the following headings:

regulation
tax
subsidy
education
research and development
purchasing

For the most part these categories are self-explanatory. The interrelationship between tax and subsidy should be examined briefly. There are a number of forms in which a subsidy can be paid. Many of them are easily recognizable as subsidies; some are not. Federal subsidies at the present time range from outright payments (Aid to Dependent Children payments, G.I. Bill benefits) through conditional support subsidies (loan guarantees for college tuitions or to overseas investors) to indirect subsidies such as tax exemptions and deductions. The shortcomings of indirect subsidy through tax exemption has been criticized on the grounds that, once granted, the amounts of such subsidies cannot be controlled, and that they conceal certain types of federal support from the public while other forms of support receive disproportionate publicity.

For these reasons, and because both waste reduction and resource recovery are currently politically popular, we discuss financial support in terms of direct subsidy. Political or economic circumstances independent of solid waste management considerations may make some degree of indirection more appropriate. The subsidy values we discuss could be translated into the less direct terms of income tax relief in the form of credits or accelerated depreciation, depletion, or other forms of deduction allowances if it would serve the public interest to do so.

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B. REDUCING WASTE GENERATION

1. General

There are a number of theoretically possible governmental actions to reduce waste generation. The government may intervene so as to reduce the amounts of packaging utilized in retail sales, it may set product specifications that will increase the useful life of durable goods, and it may penalize the utilization of throw-away or disposable products from paper towels to beverage containers. It may also impose penalties for waste generation; that is, vary the charges imposed on individual households for waste collection and disposal in proportion to the amounts of waste generated. The following paragraphs describe some of the specific steps that might be taken by the federal government to encourage waste reduction.

2. Regulation

The most direct form in which regulation could reduce waste generation would be through product specifications. As an illustration, putting First Amendment difficulties to one side, a statute might be written prohibiting the distribution of newspapers or magazines containing more than a specified number of pages or of more than a specified weight. Similarly, legislation might prohibit some forms of packaging (non-returnable containers) or of disposable products (paper plates, paper diapers, wooden shipping pallets) so as to require the use of reusable alternatives. Regulation also may be used to reduce waste generation by increasing durability of goods directly by setting minimum performance specifications (automobile tires), or indirectly by creating institutional responsibilities that would tend to encourage long product life (requiring tire manufacturers to rent tires to customers instead of selling them).

3. Taxation

We will consider under the heading of "taxation" the imposition of excise or sales taxes or their equivalent. Income tax relief, in the form of credits, accelerated depreciation, depletion, or other forms of deduction allowances will be considered under the heading "Subsidy" that follows.

Nearly all the results attainable through regulation directly could be indirectly brought about by taxation. Products failing to conform to desired specifications may be subjected to discriminatory tax rates tending to discourage their use. Throw-aways of all kinds, for example, could be placed under a tax high enough to make their use uninviting. Similarly, a tax may be imposed upon goods intended for repeated use that do not meet specified performance standards, and hence may be expected to require frequent replacement.

Taxes can also be used to discourage waste generation in a number of ways that regulation could not. It would be difficult, by direct regulation, to prohibit industrial processors, commercial establishments, or consumers from generating wastes. However, a tax on waste output, a "user charge," graduated according to the amount of waste produced (either to act as a deterrent or to reflect the increase in costs to the municipality of greater waste loads), would discourage waste generation sufficiently to accelerate some waste reduction investment that might not otherwise take place or to encourage commercial enterprises and householders to limit or eliminate their purchases of throw-away or low-durability items. This in turn would justify installation of equipment (shopping carts, washing machines) to relieve a household of some of the inconvenience or expense of using durable products, from shopping bags to diapers, to perform functions for which the household would otherwise use disposable products. Similarly, commercial enterprises would have an incentive for capital expenditure to eliminate large volumes of paper waste generation. Visual electronic display of recorded or computed data, for example, would replace multiple print-outs of results of automated data processing to a greater degree, were the discarded print-outs to result in a tax liability. An alternative waste output tax would be a "value subtracted tax" in which a materials balance account would show the difference between raw material input and product and energy output. The difference between input and output would be taxed.

In conjunction with resource recovery enhancement, waste generation taxation would be particularly effective if wastes destined for resource recovery (and given any necessary special handling) were exempted from a waste-generation tax.

A number of waste generation reduction tax proposals are pending in state legislatures and in Congress. Most are directed at reducing household wastes. Some impose a tax on non-recyclable containers, others on packaging by weight. Other taxing proposals urge that packaging be categorized according to the difficulties that each type poses for waste disposal and that differential tax rates be imposed to encourage the use of the less troublesome materials.

4. Subsidy

Some of the consequences that could be brought about by waste generation taxes could be encouraged by subsidy. Consumer purchase of reusable products or of products meeting demanding durability standards could be rewarded by an associated subsidy. Reduction in waste output could similarly entitle a waste producer to payment; so could purchase of equipment that would reduce waste, or purchase of equipment that would permit the use of durable or returnable products in place of disposable ones. Subsidies can be in the form of cash payments or in the form of tax relief. Existing cash price supports for many agricultural products have crop limitation requirements; such subsidies as the existing individual income tax exemptions could be made conditional on limiting waste output.

5. Education

Industrial and commercial waste generation are not likely to be reduced by any education programs; household waste production might be. The use of many disposable products in preference to reusable products is a relatively recent phenomenon and one that could, for some consumers, be reversed by a public information effort. Some families have experimented with such procedures as using shopping bags, purchasing products with the least possible packaging, and avoiding disposable products. A program in which householders were informed of the annual increase in per capita waste generation and of the resulting increases in municipal costs (and in their resulting taxes) would, at least marginally, reduce waste production.

6. Research and Development

A federally financed research and development program to develop alternatives to conventional packaging to permit the curbing of non-packaging paper uses and to extend product life of semi-durable products made of combustible materials, would reduce the rate at which households and some service establishments generate waste. Preservation of foods in forms that require less packaging would be one form for such research; another would be developing methods for making information available that would otherwise be printed or mailed but is not needed in a permanent form. Research that would lead to systems permitting electronic display of telephone numbers, credit transactions, classified advertisements, special interest news, and retail product advertisement would help reduce the volume of household waste.

7. Federal Procurement

Federal procurement practices could have effects on reduction of waste generation similar to some of the other actions discussed above. Government procurement can create a special market for reusable products so as to reduce their unit cost of manufacture and deny such a market to disposable products. The consequence would be similar to a subsidy to reusable products and a tax on disposable ones. Government procurement can create a guaranteed market for as yet undeveloped technology so as to encourage private capital to invest more in R&D to develop such technologies than non-governmental demand would warrant. This could have the effect of stimulating private R&D in package-free preservation of perishables, or low-cost electronic display of data comparable to the effect of direct government-supported R&D.

8. Discussion

Waste reduction is not a promising opportunity for governmental action with respect to manufacturing or agricultural waste generation; it holds some promise for reducing generation of consumer and commercial wastes.

As Chapter III of this report indicates, the amounts of combustible wastes generated by manufacturing are small compared to the waste stream generated by agriculture and compared to municipal waste. Manufacturers already have an economic incentive not to create waste; they also have a considerable degree of control over their processes and equipment so that where an opportunity to avoid waste is technologically feasible, they are able to adopt it, if by reducing waste they reduce costs. The consequence is that, for the most part, the newer and larger the scale of a manufacturing plant, the lower its wastes per unit output. Stated another way, the government has only the opportunity to effect a marginal change in a process of waste generation reduction that is already at work.

Reduction of agricultural waste generation presents very little actual opportunity for successful governmental action. The only action that could be taken, even theoretically, to reduce agricultural waste problems would be certain to meet very great popular opposition. Animal waste production correlates directly with per capita human consumption of animal protein. There is no question that a combination of meat, milk, and egg rationing, high taxes on all animal protein products, a public education program to encourage substitution of vegetable proteins, government-supported research and development of new protein sources, and reduced government procurement of animal proteins could theoretically reduce animal waste generation to some arbitrary fraction of its present and forecast volumes using existing technology. However, such a program, in peacetime, would neither be popularly nor politically acceptable as a means of dealing with a solid waste problem.

With respect to household wastes, consumers have only marginal control over the amounts generated. However, they have some opportunities, from buying packaged consumables in bulk, to avoiding a number of one-time-use "disposables," to reduce waste generation, almost always at the cost of greater inconvenience. However, they have no option by which to avoid all packaging or most of their purchases of non-durables, e.g., personal or household items made of textiles, leather, plastics, paper or cardboard.

Commercial activity is midway between manufacturing and household consumption. It has much greater control over the waste generation consequences of its purchasing and a profit incentive to encourage reduction in waste generation where it results in reduction of costs. However, just as increased waste generation for a householder is most often the result of seeking the most convenient alternative, increased waste generation for a commercial enterprise may often result from using the least expensive alternative (throw-away hypodermic syringes, plastic cups, paper towels), accepting increased waste disposal charges rather than paying the labor and equipment costs for processing reusable alternatives.

There is little opportunity for reduction of combustible wastes through regulation primarily because direct regulation causes greater disruption of existing market structures or of consumer habits than other forms of governmental action. Limiting newspaper size would have a particularly dramatic effect on readers, editors, and advertisers. A regulation that required sales of consumer goods only in bulk packages would reduce the number of packages sold but each purchase would require the consumer to pay, carry, and store more. The foreseeable disruption can be translated into unpopularity with consumers and this, in turn, into legislative resistance to regulatory proposals.

There are, in addition, unresolved constitutional questions relating to the scope of the federal government's authority to regulate products' specifications for the sole purpose of reducing municipal waste disposal problems.

Because the federal government's power to tax is broader than its power to regulate directly, the taxing alternatives to product specifications are not subject to the same constitutional restraint as direct regulation. If the taxes applied are low enough to impose a deterrent to purchasing rather than a prohibition, their impact on existing markets would be less disruptive than that of regulation, but it would also have a more limited effect on solid waste generation. If the product specifications favored by the tax were sufficiently inconvenient for the consumer, that he continued, for example, to purchase the heavily taxed smaller packages, the effect of the tax would only be to raise the cost of living.

User charges, or local taxes on the generation of wastes, have the appeal of placing the costs of waste disposal on the activity generating the waste. Administratively, they would require the municipality only to record the weight of containers emptied for each dwelling at each collection, and to base charges on the resulting totals. They suffer from two drawbacks, the householder's marginal degree of control over his ability to obtain goods without packaging and the likelihood that, where a user charge is large enough to markedly influence buying decisions, it will also increase litter problems by encouraging householders to divest themselves of waste in ways that will not increase their user charges.

Tax proposals aimed at reducing packaging by taxing packaging materials by weight have the drawback that they may cause a change in conduct other than the one intended. A tax on containers and packaging based on weight will have the effect of increasing the substitution of aluminum for steel and plastics for other packaging materials rather than reducing the volume of packaging used. Related proposals that categorize packaging materials, according to the difficulties that each poses for waste disposal, and apply different rates to different categories to encourage the use of less troublesome materials are administratively troublesome. They call for cost-consequence classification among materials that may be combined in many complex forms. Such classification is limited by its necessary reliance on specific established waste disposal technologies at their present state of development. Plastic and old tires may be non-biodegradable in a sanitary landfill but valuable sources of energy in a combustion process that recovers heat.

Waste reduction subsidies have the same shortcoming as user charges; they place a premium not only on selective purchasing but also keeping waste out of authorized collection receptacles. The result cannot be estimated without experimental testing programs, but increased litter resulting from clandestine disposal is likely.

Research and development to reduce waste output provides less opportunity for significant results than other forms of research and development because industrial processing and commercial services already carry with them a profit incentive to reduce waste. A federally financed research and development program to investigate the process-by-process technological opportunities to reduce waste would duplicate private efforts that are carried out in the absence of such a program. Consumer wastes are another matter. Containers and packaging serve to make their contents portable, to preserve them, and to enhance sales appeal. R&D that resulted in food or other product preservation with less bulky packaging would reduce consumer waste but only to the degree that the products would be equally portable and saleable in the modified containers. R&D directed at supplying consumers electronically with information of a sort that is otherwise printed or mailed, such as telephone numbers, credit transactions, and retail product, employment, and real estate advertisement would also affect waste generation but at a rate reflecting the fact that non-packaging paper entering the waste stream weighs only one-fifth as much as packaging materials.

Government procurement aimed at encouraging waste reduction research and development would be at best an indirect means to achieve what is already a limited goal.

C. IMPROVING WASTE DISPOSAL

1. General

The emphasis elsewhere in this report on incentives and disincentives to modify the size and composition of the waste stream and to promote the recovery and sale of resources from the waste stream derives in part from the congressional mandate in the Resource Recovery Act of 1970 and in part from projections of future population concentrations.

It should be considered, however, in the perspective of an existing waste management system in which disposal through open dumping, sanitary landfilling, and incineration accounts for virtually all collected waste. Population growth and relocation over the next twenty years will tend to increase population concentrations in some regions dramatically. In 1970, 68.6 percent of the population lived in standard metropolitan statistical areas (urban areas encompassing cities of 50,000 population or more). By 1990, 80 percent of the population will live in such areas. Out of a population that will be between 247 million and 277 million, approximately 178 million, or around half, will live in cities of 130,000 or larger. In 1970, population density in the Northeast had reached 300.4 persons per square mile, with a high of 902.5 in Rhode Island. In the Middle Atlantic it was 370.8, with a high of 953.1 in New Jersey. By 1980, the New York zone (covering southeast New York State, southern Connecticut and northeastern New Jersey) is expected to have an average density of 1,863 per square mile and a total population of 24 million. These patterns of growth and projections have generated the present interest in capital intensive methods of managing waste that require relatively small land areas; but they should not obscure the fact that in areas not subject to this level of development, sanitary landfill will continue to be the preferred waste management technology. Moreover, whether or not a resource recovery incentive program is put into effect, disposal, specifically landfill, will remain an important part of waste management.

Heretofore, the federal government's primary role in solid waste management has been to encourage improved methods by carrying out or supporting research and development and innovative pilot programs of collection and disposal, and by carrying out an information program directed at both municipal officials and the public.

Research has been undertaken on improved incinerator design, innovations in collection of wastes, the environmental consequences of leaching from sanitary landfills, land spreading of sewage sludge, and the effects of shredding or compacting of wastes prior to landfilling. There has also been federal support for pilot program investigation of the economics and acceptability of long-range rail haul of municipal wastes to remote landfill sites. The most extensive public information program devoted to a specific solid waste management goal has been an effort to terminate the utilization of open dumping by municipal governments and to substitute sanitary landfilling.

The future role of the federal government in relation to disposal as a form of waste management is likely to be somewhat more direct than the actions taken heretofore.

2. Regulation

Promulgation of emission standards for stationary sources of air pollution has already had an indirect effect on incinerator operation and design. Water pollution standards similarly affect sanitary landfill design. Prohibition against ocean dumping of municipal refuse is an example of direct federal regulation of waste management. Direct federal regulation requiring the closing of all open dumps or setting specification for incinerator and landfill design are possible extensions of the present controls. Long-range rail haul to transport municipal waste, or incinerator residue, to remote landfill sites will be affected by freight rates; federal rate-setting authority could alter the economics of such rail hauls.

For some densely populated states, lacking any further landfill sites within their boundaries, interstate transportation of wastes will be a necessity. Under such circumstances, these states and the municipalities within them will lack the land condemnation power necessary to assure the availability of landfill sites. Federal action to provide for regional disposal planning and granting land condemnation authority to interstate planning agencies may be necessary.

3. Taxation

A federal tax could be imposed directly on the operation of an open dump, sanitary landfill, or incinerator of substandard design if direct regulation were held to be unconstitutional.

4. Subsidy

Federal subsidies to communities that improve their waste disposal practices are likely to produce more immediate change than the public information effort now under way to encourage the closing of open dumps. Subsidies could be tied to the rate of waste disposal or number of persons in the community; the latter would be administratively simpler. An alternative that would produce the same result, without the expenditure of additional funds, would be to penalize communities that do not abide by approved waste disposal standards by withholding all federal funds otherwise available to the community, either under a general revenue sharing program or under specific federal assistance programs. This procedure, adopted by Title VI of the Civil Rights Act of 1964, has two drawbacks. It penalizes the individual beneficiaries of federal aid without ensuring compliance by the public officials charged with waste management. It also requires an extensive administrative load to develop and disseminate the federal standards and to ensure compliance with them.

5. Education

Federal public information programs may be used to encourage community support for improved municipal waste management practices even though the improvement imposes increased costs on taxpayers. Such programs also can be used to familiarize the public with the factors that make sanitary landfill less aesthetically offensive than open dumping in order to overcome public antipathy to landfill sites in close proximity to urban areas.

6. Research and Development

Further research on incinerator emission control technology funded by the federal government would reduce capital and operating costs of such equipment. Further federally supported research of the consequences of sanitary landfill leachate entering surface and ground water supplies is needed to determine whether landfill design should be revised.

7. Federal Procurement

A government policy of preferential procurement of incinerators of advanced design would help attract private capital into further emission control research and development and would reduce the unit cost of innovative equipment by providing a large-scale market for it.

8. Discussion

The role of the federal government in improving waste disposal practices has already been established. New governmental initiatives in the direction of source reduction or increased resource recovery will not obviate the need for disposal or the desirability of improved disposal. There is one aspect of disposal that will require innovative treatment. Population growth patterns will intensify the need for workable long-range rail haul disposal of wastes, requiring, in many cases, interstate or regional planning and cooperation, and a land condemnation mechanism to assure the availability of disposal sites.

D. INCREASING RESOURCE RECOVERY

1. General

The following discussion indicates some federal actions that could increase the extent to which resources are recovered from waste flows. All six classes of governmental action offer an opportunity for encouraging resource recovery. Moreover, there are opportunities for increasing such recovery from agricultural and industrial, as well as municipal, wastes. One qualification to the alternative actions described here should be kept in mind.

Before deciding upon any action that would give preferential treatment to the sale of products incorporating resources recovered from wastes, the government should consider to what degree the resource to be recovered may be intermingled with resources not derived from wastes before its reuse. This may occur in such a way that producers utilizing the waste-derived resource cannot determine what fraction of their product consists of the recovered resource. Where, for example, paper fibers are recovered from solid waste, the paper manufacturer using them will know what proportion of his input is recovered material. A chemical manufacturer may be able to distinguish chemical feedstock derived from pyrolysis of wastes from feedstock originating in petrochemical refineries. However, customers for various forms of energy, process heat, electrical power, or methane may not be able to distinguish the degree to which they are utilizing a waste-derived resource. This difficulty may interfere with programs to grant benefits to processors utilizing recovered resources.

2. Regulation

Regulation can be used to increase resource recovery by prohibiting or requiring various forms of activity in ways that create a market for reused materials or place virgin materials at a disadvantage. Possible regulatory actions cover a wide range of potential effects, from indirect to direct. An indirect regulatory change, such as revising labeling requirements to substitute the word "recycled" for "reused" fibers in federal regulations affecting textiles, would have a marginal effect on textile markets, tending to increase industrial fiber recovery investment. At the other end of the spectrum, the most direct form of such regulatory action is setting product or process specifications. A product specification that required newsprint to include not less than 60 percent recycled fibers, for example, would justify plant relocation and investment to take advantage of the new market. Such specifications may be imposed on a number of product markets with varying degrees of difficulty and varying side-effects. Some industries, such as thermoplastic resin manufacturers, regularly use plant scrap of known specifications for as much as 30 percent of the input for their production. Requiring them to use post-consumer scrap in their products, even assuming the plastics could be sorted by type and color, would sharply affect performance or, in some cases, require that non-recycled component of feedstock have characteristics that could offset the undesirable characteristics of the post-consumer scrap. The result of post-consumer scrap reuse specifications under such conditions would be to create a new plant scrap disposal problem that would increase in proportion to the utilization of post-consumer waste. Another aspect of product specification to be considered is the effect of specification demands on industries that are now located near sources of supply of virgin raw materials. At the present time, the majority of corrugated paperboard plants are located close to the forests that supply them with pulp. Requiring that reclaimed fibers from mixed municipal waste be incorporated into paperboard liner would substantially increase costs of production by the amount needed to haul reclaimed fibers from population centers to these remote plants. Relocating such plants close to urban sources of supply for reclaimed fibers would only make economic sense if the expected product were made entirely of reclaimed fibers or at least of so large a percentage of them that transportation costs of any needed virgin fibers from forest sources could be absorbed. In general, setting product specifications by federal regulation to increase utilization of recovered resources would require detailed consideration of environmental and economic consequences of each such action with respect to each product for which specifications are to be set, not only as these consequences would appear in the industry making the product, but also as they would affect the economic activities supplying that industry and its customers.

Process specifications, at least in energy production, are another opportunity for encouraging resource recovery. Fossil fuel burning power production could be subjected to a process requirement that 10 percent of all fuel input be municipal refuse.

Government regulatory powers may be exercised to bear directly upon the profitability of resource recovery technologies. Federal agencies set or approve rates charged for transporting various forms of energy transmitted in interstate commerce as well as interstate shipping costs for other products. Exercise of these powers as they affect transportation costs would directly affect resource recovery. Recovery of paper fibers from municipal wastes is not currently economical because paper plants are located near forests rather than cities. Preferential transportation costs would overcome part of this cost burden by moving recovered fiber from urban sources to mills more economically, or, for paper mills built next to urban fiber recovery plants, would reduce the cost of shipping pulp wood needed to upgrade the urban fiber, from forests to cities.

3. Taxation

Tax measures to increase resource recovery have the advantage of being somewhat more flexible and hence less disruptive than direct regulation. Rather than requiring that newsprint be made of some required proportion of recycled fibers, the government may impose an excise tax on newsprint, graduated to reduce the tax in proportion to the reused fiber content. The tax alternative would have several advantages over regulation. Opposition to such government action would be less than against regulation because when special circumstances are sufficiently compelling to override the tax incentive, the consumer is free to pay the tax and utilize the nonrecycled alternative. The excise tax also is free from some of the Constitutional constraints upon federal regulatory power. Although in recent years, the courts have greatly broadened the reach of federal jurisdiction based on the commerce clause, federal regulatory action is still subject to the requirement that the action regulated affect interstate commerce. The taxing power is not subject to any such restraints. Energy or products made, transported, and sold within a single state could be subjected to an excise tax regardless of their impact on interstate commerce. In addition, the federal government in its regulatory actions has been held to the standard of equal protection made applicable to state governments by the 14th Amendment. Equal protection might militate against regulating one of a class of products and not other members of the class. The taxing power is not so circumscribed; the federal government is free to tax the sale of any product or service, whether to raise revenues or discourage the product's use. In the past, it has done the latter by imposing heavy taxes, for example, on gambling, the transfer of narcotics, and submachine guns.

Resource recovery tax proposals, like the waste generation reduction tax proposals devised earlier, are also pending in state legislatures and in Congress. Some purport to place an across-the-board tax on all products, computed by weight, subject to a credit based on the proportion of reused material in the product; others propose to authorize a regulatory agency to draw up schedules of taxes and credits on a product-by-product basis. In evaluating across-the-board taxes, it must be determined what proportion of the products to which they would attach could, in fact, utilize substantial amounts of resources from wastes. Where a product could utilize a high proportion of reused fiber, like paperboard liner, a tax might be an effective incentive. Many products, however, from rubber tires to nylon stockings can use either very small amounts of the material reclaimed from post-consumer waste or none at all. A tax on these products will produce revenues and a rise in the cost of living, but will only increase resource recovery where the demand for the product is elastic because of substitution opportunities among competing products that can utilize resources from waste. Taxes imposed on products by weight may even reduce resource recovery where lightweight products using no recovered resources (plastics) become relatively cheaper than competing heavier products that use substantial proportions of recovered resources, but would still be subject to higher unit costs because of the tax.

These anomalies could be avoided only by a tax schedule arrived at after considering, for each product to be taxed, whether the tax would increase use of recovered resources in the product, or in other products likely to be substituted for it.

4. Subsidy

Subsidy payments may be made to municipalities generating wastes, to processors preparing waste-derived materials for reuse, or to customers for waste-derived products. Subsidies proportional to utilization of recovered resources are a direct method for promoting resource recovery. Subsidy is more straightforward to control, audit, and measure the effects of, than regulation or tax strategies.

Payment may be based upon weight of waste utilized or value of resource recovered. The shortcoming of a subsidy paid for weight of waste utilized is that it tends to encourage inefficiency, rewarding a large flow of material, even where the bulk of that material is only marginally reduced and the resulting resource of slight, or nonexistent, value. Payment in accordance with the value of resource recovered also rewards extraction processes, like those for vitamins, in which the effect on waste reduction would be small, either because the market for the resource was small or because the process extracted only a small amount of the mass to which it was applied. It also would be vulnerable to fluctuations in the value of the recovered resource which resulted from either normal market fluctuations or over-supply resulting from the impact of the subsidy itself.

A hybrid subsidy with elements of both waste flow and resource value subsidies avoids the problems of both. Such a subsidy would pay a bounty for each pound of waste utilized subject to a debit for amounts of waste remaining after processing. The difference between the two could then be multiplied by a factor representing the unit value of the resource recovered. The resulting subsidy would offer an incentive to absorb as much waste as possible, to utilize it in a way that reduced its volume or weight as much as possible, and utilize it in the way that produced the most valuable resource.

A subsidy that would produce a similar effect for non-energy forms of resource recovery would be a subsidy to a manufacturer computed on the basis of the proportional weight of recovered waste material incorporated into his final product.

The most important obstacle to subsidies based on weight of waste processed or utilized is the administrative, record-keeping, and enforcement burden created by such subsidies. These difficulties do not arise with a subsidy paid to municipalities based on population.

Another subsidy that would avoid administrative problems common to weight-based subsidies would be payment to the processor who, by separating, pulping, chopping or otherwise altering a waste product, makes it suitable for sale to a manufacturer or to consumers as a usable material, where such payment was calculated on the value of his sales.

Tax credits or deductions are a form of subsidy which is more appealing to both legislators and recipients than cash subsidy because they are less visible and hence somewhat less vulnerable to the pejorative associations of "hand-out" or "give-away." Such a tax relief subsidy based on sales would be acceptable where a direct subsidy would be criticized as inequitable government support for artificially high profits.

5. Education

There is a significant opportunity for governmental action to reinforce popular support for resource recovery. Both governmental and non-governmental agencies have traditionally displayed a bias against secondary materials, either as a result of experience with poor quality control in products using recovered material, or of pressure from representatives of organized major suppliers of primary materials. The result has been labels and specifications giving preferential treatment to material being used for the first time and attaching pejorative associations to "used," "reused," or "reprocessed" materials from mattress stuffing to electric wire insulation. The popular support being demonstrated by the operation of small-scale recycling centers under the sponsorship of local private organizations or the glass or aluminum industry, and consumer interest in recycled paper products, suggests that recovered resources in consumer products have market advantage over new materials in products in which their performance and cost is comparable with that of new materials. A government campaign encouraging household purchasers to give preference to products using recovered fibers, ranging from school supplies and stationery to paper bags, cartons, and newsprint, would be likely to create a sufficient demand for such products to overcome some modest differential in price.

Apart from the opportunities to increase demand, a public education program will be necessary to maintain popular support for any environmental improvement programs that either directly raise consumer costs, as excise taxes do, or indirectly, as imposition of product specifications might by raising manufacturers' costs, or as government subsidies might, by increasing the need for government revenues and hence other taxes.

6. Research and Development

Federal R&D investment is the most visible influence in the development of new technology for resource recovery. Private investment has been responsible for initial conceptual work and laboratory scale development, but, with a very few exceptions, federal funding has been the dominant influence in larger prototype and pilot plant construction. This is in part because investors seeking support for development are aware of the existence of a federal research budget for resource recovery and are less certain of the identity and location of private capital sources. A more important factor, however, is the relatively marginal profit opportunity in the resource recovery technologies that have emerged to date. In the absence of non-market incentives supplied by governmental action, the sum of projected development, capital, and operating costs even for the most advanced systems described in the following chapter is so great as to place the resource to be recovered at a competitive disadvantage compared with primary materials or to leave them only a slight and somewhat speculative possible advantage. The incentive for private finance in recovery systems, where it exists, is less the expectation of profit to be made from sales of recovered resources on open markets than it is expectation that environmental concerns will compel more extensive waste processing at a cost that justifies resource recovery that would otherwise be too expensive to justify itself as part of a low-cost waste disposal system.

7. Federal Procurement

Wherever resource recovery is better than a break-even proposition, the existence of a substantial and stable demand for a product utilizing the recovered resource will, in itself, lower costs for the producer by reducing marketing costs. This effect is most significant where the government-created demand exceeds capacity. The government may place purchase orders in excess of capacity with this interest in mind. EPA's Clean Car Incentive Program is an example of such a purchasing program in which developers of innovative low emission automobiles are guaranteed a minimum number of sales at a premium price if they are successful. Government purchases need not be the sole market for a recovered resource product to reduce cost of sales so long as such purchases cause demand to approach or exceed capacity. Federal agricultural assistance programs combining crop purchases with acreage limitations are an example of such a mechanism in which the federal program is intended to prevent or absorb excess supply at a foreseeable price upon which the producer can rely in planning his production investments.

These examples suggest several forms that government purchase programs might take. The simplest would be the program now under EPA study in which government requirements are reviewed to determine where product specifications can be altered to give preference to products in proportion to their recovered resource content. To the extent that such a program creates demands for products not otherwise in demand, it would provide a temporary incentive for producers to pay the costs of incorporating recovered resources into their products. The incentive would last until enough producers entered the market so that capacity outran both government requirements and non-government demand, stimulated by, or at the same time as, government demand.

A more complex government purchase program might incorporate aspects of both crop support programs and federal timber rights leasing programs. Fiber recovered from municipal waste could be purchased at a fixed price by the government and resold to paper and fiberboard manufacturers at market price. Lessees purchasing federal timber rights for use in pulp production might be required to purchase a quantity of recovered fiber from federal fiber stockpiles proportionate to the quantity of new timber they wished to acquire.

8. Discussion

The basis for federal action to encourage resource recovery is somewhat less evident than the basis for actions to reduce waste generation and to improve waste disposal. Programs to reduce generation and improve disposal need only be examined for their relative cost effectiveness because the desirability of both as goals is established by the rising cost of disposing, in a satisfactory way, of growing quantities of waste and the aesthetic and health repercussions of utilizing unsatisfactory disposal methods. The decision to encourage resource recovery is more complex. Resources are already being recovered where current market demand is great enough to support a price sufficient to pay the costs of recovery. Government intervention is necessary to promote resource recovery only where market demand is not yet sufficient to support extraction of resources from the waste stream. The best rationale for such extraction in the absence of sufficient demand to make it currently profitable is that (1) extraction of resources from virgin materials has adverse environmental effects, (2) resource recovery reduces the weight or volume of residues to be disposed of, and (3) the sale of recovered resources produces revenues to help reduce disposal costs. Such resource recovery increases the national inventory of both renewable and non-renewable resources.

Finally, Congress has explicitly required the investigation of resource recovery in the 1970 Amendments to the Solid Waste Disposal Act when it inserted the requirement that the Environmental Protection Agency study:

(1) means of recovering materials and energy from solid waste, recommended uses of such materials and energy for national or international welfare, identification of potential markets for such recovered resources, and the impact of distribution of such resources on existing markets;

(2) the use of federal procurement to develop market demand for recovered resources; and

(3) recommended incentives (including federal grants, loans, and other assistance) and disincentives to accelerate the reclamation or recycling of materials from solid wastes, with special emphasis on motor vehicle hulks.

V. RESOURCE RECOVERY TECHNOLOGY AND EVALUATION

This chapter examines the technical choices available for managing and extracting resources from combustible solid waste, and gives the pros and cons for each approach. The first part of the chapter explains the factors used to evaluate the available technologies, while the second part introduces the specific technologies. The markets for the resources that may be extracted are discussed, and each technology is evaluated. As the goal of this chapter is to identify those resource recovery technologies that may be of the greatest significance in large-scale combustible solid waste management, each technology is evaluated only in terms of its application to a major waste stream that constitutes a significant disposal burden: municipal refuse, animal manure (particularly cattle feedlot manure), or sewage sludge.

A. EXPLANATION OF THE EVALUATION PROCESS

Technical evaluation was broken into three sections:

Derivation and justification of the factors by which extraction technology should be judged;

Rating of the technologies for important waste streams against the evaluation factors;

Derivation and use of a methodology for selection of the most promising extraction technologies.

To a great extent the question of how heavily a given technical factor should be weighted and to a lesser extent the selection of the evaluation factors themselves are not purely technical matters but have policy implications. There can be legitimate differences in the overall technical assessment of a given technology depending on the varying interests and instincts of the people involved. This chapter will show both the evaluative procedure used and the technical data upon which its conclusions were based to enable other users of the data to reassign criteria and weights for different evaluations should they so choose.

1. Selection of Evaluation Criteria

We have selected five factors or criteria for technical evaluation. They are:

a. Net cost
b. Amount of waste reduction

c. Flexibility
d. State of development
e. Natural resource conservation

These factors are described in detail below.

a. Net Cost

Cost is obviously an important factor in choosing a technology. The cost has been expressed as the net cost to dispose of a wet ton of waste in a waste processing plant of a particular size. A specific plant size was chosen for each of the three major waste streams, depending upon consideration of the typical concentrations of the wastes to be treated, and of the size for which most technologies began to realize significant economies of scale. The costs have been broken into four main areas:

(1) Capital Costs. Capital costs are given in terms of capacity (dollars per daily ton) and on an annualized basis prorated across the annual capacity (dollars per ton). Included in the capital cost are all the normal capital equipment costs, such as plant, equipment, site preparation, working capital, etc., but not land.

In order to amortize capital costs, parameters such as life span, interest rate and salvage value have been assumed to be those suggested by current equipment manufacturers. In cases where no such quotes were available, approximations were made by the researchers, usually adopting values of: life span = 15 to 20 years; interest rate = 6 percent annually; salvage value = 0.

(2) Operating Costs. Operating costs are expressed in dollars per ton of waste treated. These include the cost of landfilling whatever residue is left as well as meeting anticipated air and water pollution standards.

(3) Credits for Extracted Resources. These costs are expressed in dollars of extracted resources per ton of waste.

(4) Distribution and Selling Costs. Selling and distribution costs of the recovered resources have been included in terms of dollars per input ton of waste. Available distribution and selling cost estimates vary a great deal within a given industry, and the differences cannot always be reconciled with each other. In this report we have included these costs because they are the most significant single impediment to utilization of some recovered resources.

(5) Cost Updating. Since costs for various processes were available from sources in the context of differing time frames,

all costs were inflated to the same datum--January 27, 1972, utilizing the Engineering News - Record Construction Cost Index and the Chemical Engineering Plant Cost Index.

(6) Uncertainty. Where costs are uncertain for unproven technologies, an estimated cost range is given.

b. Waste Reduction

We have considered waste reduction as an important element in the evaluation of resource recovering processes on the assumption that, at least over the next twenty years, resource recovery will remain a consideration secondary to waste disposal. In our evaluation the cost of landfilling the residue left by each technology was considered as a part of its costs; the waste reduction criterion was inserted to permit evaluation of technologies on the basis of waste reduction as an end in itself.

There are a number of factors that can affect volume of waste reduction. These are:

(1) The size of the waste stream the process can be applied to. For instance, a process that only worked on waste quail eggs would be rated very low here because of the insignificance of the waste stream involved.

(2) The inherent waste reduction efficiency of the process. For instance, a process that extracted a gram of valuable product from a ton of dried manure and otherwise removed nothing else would also get a very low mark. Even if the process were a very profitable one and could be applied to the whole waste stream it would leave the waste problem unchanged, and the decision whether or not to employ the technology would be one that would be governed by ordinary rules of supply and demand.

(3) The size of the market for the resource. Obviously if the projected market for the extracted resource is not a reasonable fraction of the amount of the resource that can be made available, the technology cannot be widely applied. Here again we do not imply that the technology should not be used, but only that it does not help solve the waste problem and hence its use should be left to the private sector.

c. Flexibility

Under flexibility we cover factors that, while less quantitative than others, have a serious bearing on whether or not a given technology merits governmental support. Factors included here were:

(1) Locational flexibility. Can the process be located where desired or not?

(2) Sensitivity to changes in waste stream composition.

(3) Future market prospects and stability.

(4) Storability of the generated resource.

(5) Adaptability to new processes for extraction of other resources; e.g., can glass extraction be easily added should it become desirable to do so?

Other special factors applicable to only some technologies were included in the flexibility category as noted in the discussion.

d. State of Development

Under this factor we dealt with two related ideas: How long will it be before the process is commercially available? And, how feasible is it? The measure of how close a process is to actual working hardware gives a measure of how much to trust its proponents' statements on cost, yield, etc. A process that can be used right now is preferable, other things being equal, to one that needs ten years' more development. In addition, it is in estimating the time until use that the question of technical feasibility itself is covered. Processes that were considered to be based on doubtful or speculative technology were assigned long development times.

e. Conservation of Natural Resources

It is important to distinguish natural resource conservation from resource recovery. A given form of resource recovery, mixing municipal waste with coal to provide fuel for power plants, may be highly efficient and inexpensive, but at the same time have only very slight effect on conservation of coal because our per capita energy demand is so much greater than our per capita waste output. There is no question, however, from a political viewpoint, that much of the popular support for development of advanced solid waste management technology is based on the assumption that resource extraction and resource conservation are synonyms or at least are very intimately related. We felt it important to state explicitly, where possible, the amount of natural resources that would be conserved if a particular extraction technology were used.

2. Weighting of Evaluation Criteria

In assigning weights to the criteria, the following procedure was followed. Project staff members individually divided a total value of 100 among the selected criteria. The results were compared, with participants who assigned the highest and lowest weights explaining their reasons for doing so. After these discussions, a second round of voting took place in which the weights assigned typically converged. These discussions also resulted in more precise definitions of what was to be considered in each criterion and some redefinition of criteria. The results when agreement had been reached were:

Cost	33
Waste reduction	28
Flexibility	12
State of development	19
Conservation of resources	8

For each criterion a technology was given one of four possible ratings: "poor," "fair," "good," or "very good." These were assigned the numerical values of 1, 2, 4, or 8. The reasons for using a logarithmic rating scale of only four values are given in references 22 through 25. In general, the values on a logarithmic scale are used because more precise refinement would be artificial since data in some areas is imprecise, and the literature on decision-making theory cited above indicates that human beings distinguish among values along a logarithmic scale.

To get a total score for a particular technology, its rating in each category is multiplied by the numerical weight of that category and the results summed for all five categories. For example, the highest possible score would be 8x33 = 264 plus 8x28 = 224 plus 8x12 = 96 plus 8x19 = 152 plus 8x8 = 64, or an overall rating of 800.

3. Standards for the Application of the Criteria

a. Municipal Waste

For evaluating the application of technologies to municipal waste, ratings of 1, 2, 4, and 8 were assigned to the five criteria as follows.

Net Cost. Individual processor size 400 tons per day, i.e., the quantity of waste generated by a community of 146,000 people. About 55 percent of the U.S. population lives in communities of this size or larger.

Net Cost	Rating
$c \leqslant \$5$	8
$\$5 < c \leqslant \$10$	4
$\$10 < c \leqslant \$20$	2
$\$20 < c$	1

Waste Reduction:

Fraction of Waste Stream Absorbed	Rating
More than 3/4	8
More than 1/2, less than 3/4	4
More than 1/4, less than 1/2	2
Less than 1/4	1

Flexibility. In applying this factor we considered each of the elements of flexibility described above and then gave a generalized response to the question "How well does this technology satisfy these elements taken together?" Very well = 8, well = 4, somewhat = 2, and badly = 1.

State of Development. This was based on our estimate of when the technology could be ready if development was energetically pursued.

When Available	Rating
Now	8
Less than five years	4
Five to ten years	2
More than ten years	1

Conservation of Natural Resources. An 8 was given to technologies that did the best in conserving non-renewable resources. A 4 was given to those that did a good, but not the best, job of conserving non-renewable resources, and to those that did an excellent job in recovering renewable resources. A 2 was given to those that recovered something either inefficiently or something that we did not feel was particularly important. A 1 was given to those that recovered nothing at all.

b. Sewage Sludge

For evaluating the sewage sludge technologies, ratings of 1, 2, 4, and 8 were assigned as follows.

Net Cost. Individual processor size 400 wet tons per day (96 percent water, 4 percent solids), i.e., the quantity of waste generated by a community of 109,000 people. About 58 percent of the U.S. population lives in communities of this size or larger.

Net Cost	Rating
$c \leqslant \$1.50$	8
$\$1.50 < c < \$2.50$	4

Lower ratings were not needed.

Waste Reduction. For sewage sludge the various technologies either eliminated virtually the entire waste stream or did nothing to it at all. Hence only two ratings were given--8 and 1.

Flexibility. Location and space required were the two factors that emerged as important. Ratings were assigned as to how well the technologies solved these problems.

State of Development. Ratings are the same as for municipal waste.

Conservation of Natural Resources. A 2 was given if any resource at all was recovered; otherwise a 1. This was because no resource was recovered in anything except a very small amount relative to the amount that will continue to be derived from conventional raw material sources.

c. Feedlot Cattle Manure

In evaluating feedlot manure technologies, ratings of 1, 2, 4, and 8 were assigned to the five criteria as follows.

Net Cost. Individual processor size 100 wet tons per day (85 percent water, 15 percent solids). About two-thirds of all cattle on feedlots are on lots that generate this much or more manure.

Net Cost	Rating
c < \$1.00	8
\$1.00 < c < \$3.00	4
\$3.00 < c < \$9.00	2
c > \$9.00	1

Waste Reduction. Ratings are the same as for municipal waste.

Flexibility. All technologies here were top-rated except one, methane production, which was given a 2 because it was felt that the storage and transportation problem was very serious.

State of Development. Ratings are the same as for municipal waste.

Conservation of Natural Resources. Technologies that conserved with good efficiency non-renewable resources were rated 8. Those that conserved a renewable resource in a minor way were given a 2, and those that conserved no resources at all were given a 1.

B. EVALUATION OF RESOURCE RECOVERY TECHNOLOGIES AND RESOURCE MARKETS

1. Combustion Processes

Combustion in the context of this report refers to the burning of solid wastes in the presence of air in a controlled manner in an enclosed space conforming to prevailing air and water quality emission regulations. The plants used for combustion of municipal refuse and sewage sludge and animal manure differ in configuration and are discussed independently of one another. However, the add-on steam or electricity generating systems are equally applicable to all these waste streams and are discussed together.

a. Incineration Without Resource Recovery (Principally for the Purpose of Volume Reduction)

i. Process Description

The conventional state-of-the-art plant utilizing this technology consists of the following sections.

> A receiving area, which consists of a concrete apron on which refuse trucks back up and dump their contents into a giant refuse pit (as much as 30 feet deep, 100 feet long, 20 feet wide in typical installations).

An overhead crane, which picks up refuse from the pit and delivers it to a feed hopper mechanism which feeds refuse onto the combustion grates at a constant rate.

The combustion grates, whose main functions are to move refuse through the primary combustion chamber and simultaneously agitate the refuse so that a maximum refuse surface is directly in contact with fire and subject to optimal burning conditions in the primary combustion chamber. This is the most expensive part of the combustion plant, and a large number of grate designs are available. Among the more well-known types are the moving belt, the reciprocating grate, and the drum-type rollers.

The primary combustion chamber, in which refuse is burned. A conventional refractory furnace is used for non-energy recovery systems. These are designed to supply 150 to 200 percent excess air to keep furnace temperatures down to levels that do not erode refractory material. This results in large quantities of exhaust gases in which objectionable constituents of the gases are somewhat diluted.

A "secondary" chamber in which combustion gases and particulate matter carried by combustion gases are subjected to further combustion.

A residue bin, in which the solid products of combustion and all unburnt matter is collected and quenched. The bin feeds directly into a truck which can cart the residue away to a landfill.

Air pollution control equipment, consisting usually of either wet scrubbers, bag filters, or electrostatic precipitators. If wet scrubbers are used, primary wastewater treatment equipment is usually also included in the combustion plant. This may be just a preliminary screen and a settling tank. Electrostatic precipitators require preliminary cooling of gases down to 600 degrees F prior to passage through the precipitator equipment. The most convenient way to effect this cooling is to use heat exchangers on the gases and thus produce steam.

Tall chimney stacks through which gaseous emissions are discharged.

A more recently developed incineration plant uses relatively higher combustion temperatures (2600 to 3000 degrees F compared to 1200 to 2000 degrees F) and has a different plant configuration.[26] This system uses supplemental energy in the form of very-high-temperature, preheated, combustion air provided by a super blast heater. Combustion air is filtered and then heated in the super blast heater by passing it through silicon carbide tubes around which flow the hot combustion products of a fuel, ordinarily gas or oil. The air is heated to any desired temperature up to 2000 degrees F and the temperature of the air can be increased or decreased rapidly in order to accommodate changes in demand.

During operation of the system, refuse is charged periodically by conventional means into the top of a gasifier or tower and its level is maintained within prescribed limits. As the refuse slowly descends in the gasifier, most of the readily combustible materials never reach the high temperature zone at the bottom, because the hot gases permeating up through the refuse pyrolyze the organic materials to form combustible gases.

The material which reaches the bottom is comprised of difficult-to-burn objects, ash, and non-combustibles. Temperatures at the base of the gasifier are in the range of 2600-3000 degrees F, depending on the refractoriness of the non-combustibles. A liquid mixture of inorganic and metallic materials flows from the gasifier into a chamber filled with water where an aggregate-quality frit is formed from the slag and the metal is frozen into small droplets. The gases flowing from the gasifier contain no free oxygen and consist mainly of carbon monoxide, hydrocarbon gases, and nitrogen. Entrained in the gas stream are particles of carbon, fly ash, etc. This combustible gas-solid mixture is reacted in an igniter with ambient air. It is estimated that less than 15 percent excess air is required to carry the combustion reactions to completion. The igniter operates above 2000 degrees F, and the entrance gas stream is admitted tangentially in order to fuse non-combustible material on the refractory wall of the igniter. Slag flows from the base of the igniter into a water-quench tank similar in function and operation to the tank associated with the gasifier.

The remaining equipment in the system serves to extract heat from the gases issuing from the igniter and to cleanse the gas stream of particulate matter before releasing it to the atmosphere. The last component in the system is a special fabric filter which provides removal of particulate contaminants.

Sewage sludge and animal manure incineration plants differ in configuration from these two plants just described. Many types of sludge incineration plants have been developed, including traveling-grate furnaces, rotary kiln type furnaces, fluidized bed units, wet oxidation units, atomized spray units, multiple hearth furnaces, and flash-drying units.[27] The combustion process usually consists of the following phases: the temperature of feed sludge (at 75 percent moisture content) is raised to 212 degrees F; water is evaporated from the sludge; the water vapor and air temperature of the gas are increased; and the temperature of the dried sludge volatiles is increased to the ignition point. The end products of this combustion are: water, sulfur dioxide, carbon dioxide, and inert ash.

The most popular sludge incineration unit is the multiple hearth furnace. It consists of a circular steel shell surrounding a number of solid refractory hearths and a central rotating shaft to which "rabble" arms for agitating the sludge are attached. Each hearth has openings that allow sludge to be dropped to a lower hearth. The central shaft has an inner cold air tube to cool the rabble arms while an outer tube in the central shaft is a conduit for hot air. Thus sludge is continuously fed in at the top of the unit where it is initially dried, then falls to lower hearths where the actual combustion process occurs, the remaining ash finally falling into a cooling zone. A continuous feed operation is thus possible.

Incineration of manure uses the same type of equipment as that used for sewage sludge incineration except that, since the solids content of manure is almost four times that of sewage sludge, much less dewatering is needed, and hence less supplementary fuel.

Flow diagrams for a conventional combustion plant, a high temperature combustion plant, and a multiple hearth sludge or manure incinerator appear respectively in Figures 6, 7, and 8.

Incineration costs are dependent upon a number of factors, including those that affect other solid waste processes; e.g., geographical differences affecting labor and material costs, composition and moisture content of incoming refuse, etc. Of special relevance to combustion costs are:

(1) Scale: smaller plants which can minimize on moving parts, especially on complicated grates, are much less expensive than continuous-feed, continuous-residue-removal plants. The combustion process is also easier to control in smaller chambers, thus further reducing equipment costs.

(2) Air pollution control to be effected: many small plants appear to be meeting current emission standards by merely using afterburners. However, the 1973 standards will begin to eliminate most plants which are not fitted with electrostatic precipitators, or at least high efficiency wet scrubbers, both of which are relatively costly items.

Capital costs of straight incineration (without resource recovery) of municipal refuse range from $5,000 to $12,000 per ton of daily rated capacity. The breakdown of these costs has been reported as:[28]

Buildings	20 percent to 40 percent
Furnace and appurtenances	25 percent to 50 percent
Air pollution control devices	5 percent to 10 percent
Chimneys	4 percent to 11 percent
Shredders	4 percent to 11 percent

FIGURE 6

FLOW DIAGRAM FOR A CONVENTIONAL INCINERATION PLANT

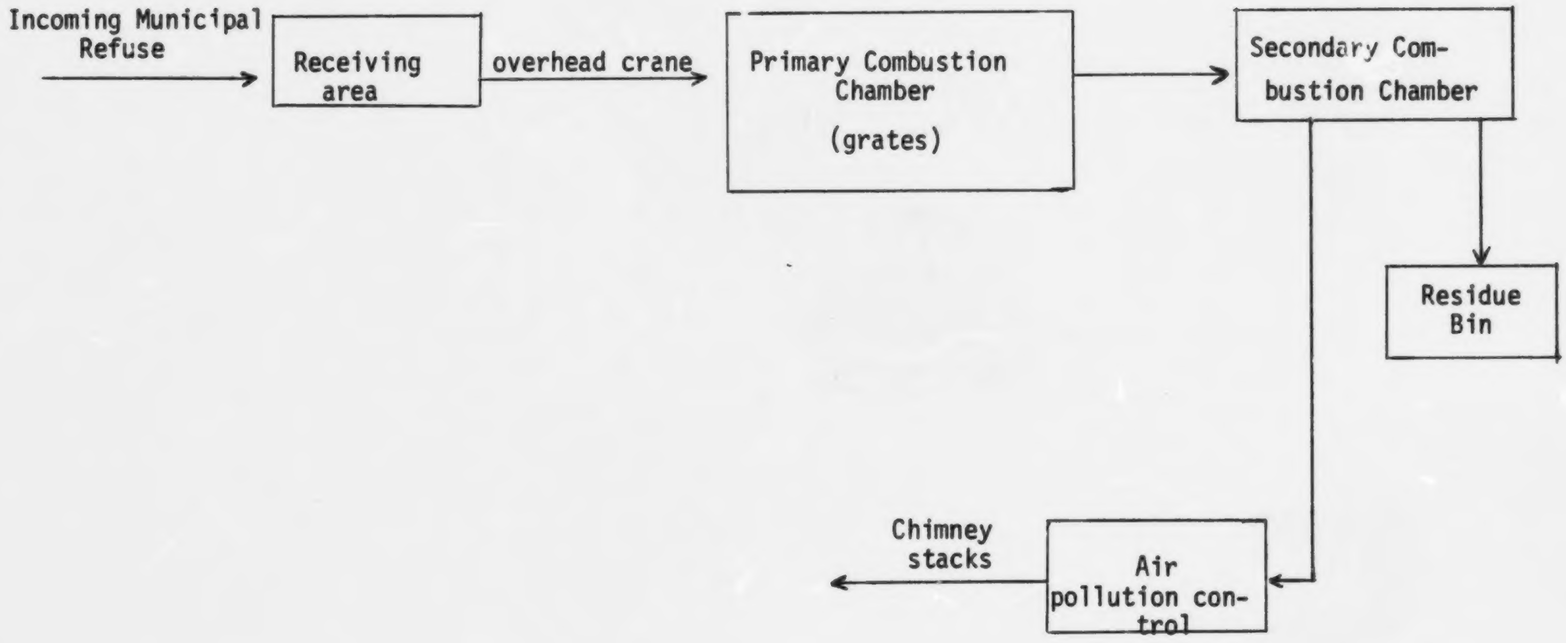

Incoming Municipal Refuse
Receiving area
overhead crane
Primary Combustion Chamber (grates)
Secondary Combustion Chamber
Residue Bin
Air pollution control
Chimney stacks

FIGURE 7

FLOW DIAGRAM FOR A HIGH TEMPERATURE COMBUSTION PLANT

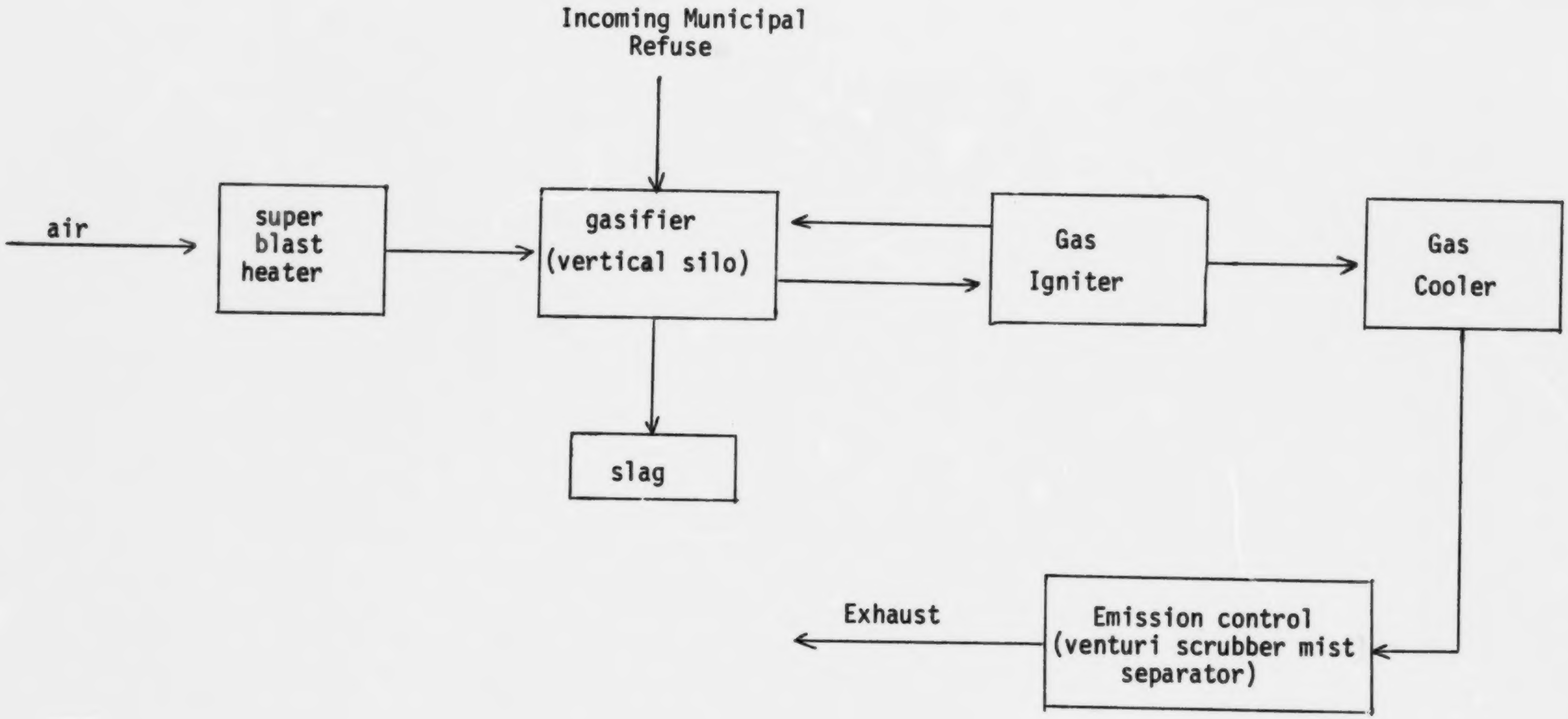
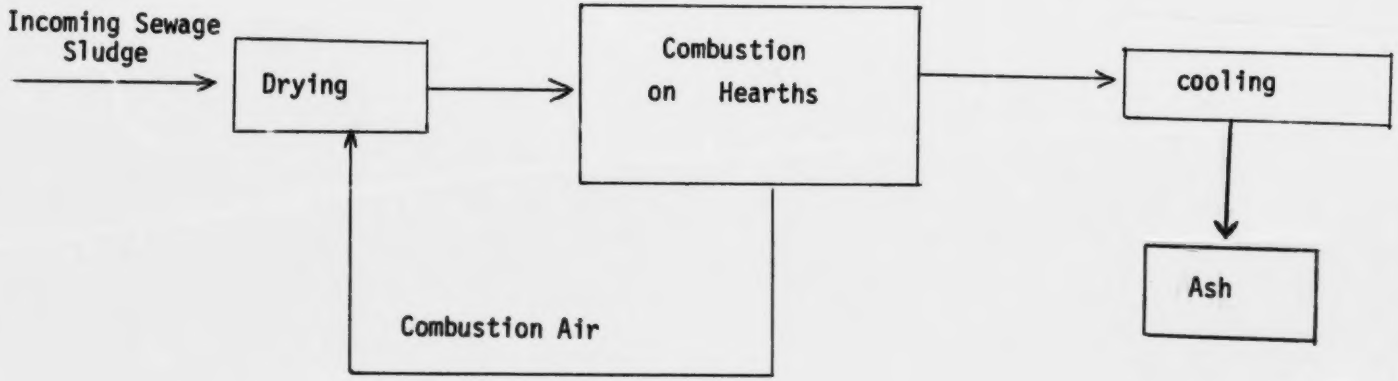


FIGURE 8

FLOW DIAGRAM FOR
MULTIPLE HEARTH INCINERATION OF SEWAGE SLUDGE (OR ANIMAL MANURE)



A study of seven combustion plants tends to bear out these costs.29 In order to arrive at a total cost for combustion, amortization over a life span of 20 years, assuming 80-90 percent incinerator utilization or availability, at an interest rate of 5-6 percent, has been taken.

Operating and maintenance costs vary from $3 to $7 per ton of input municipal refuse. Maintenance and repairs can be expected to cost from 10 to 15 percent of total operation costs. Labor and materials will account for about 50 percent each of operational costs.

Total cost ranges from $6 to $20 per ton, with operating costs averaging about 40 percent, and amortization costs about 60 percent, of this total.

A 400-ton-per-day plant for municipal refuse costs approximately $2,300,000, depending on the degree of sophistication incorporated in the plant, especially air pollution control equipment. This amortizes out to $3.30 per ton. Operating costs at this scale size are $4.70 per ton. Total costs are therefore $8 per ton.

High-temperature incineration of municipal refuse has a higher capital cost ($6,200,000, or $5.60 per ton), but a lower operating cost ($4.40 per ton), thus bringing total costs for this technology to $10 per ton, at a 400-ton-per-day scale.

Capital costs for combustion of sewage sludge (or animal manure) are very low, averaging under $1,000 per input ton (96 percent moisture) of daily capacity. Operating costs are somewhat higher, averaging slightly under $1 per input ton (96 percent moisture).

Costs for incinerating sewage sludge range from $52,000 to $146,000 for a 400-ton (96 percent moisture content)-per-day plant, which amortizes to $0.04 to $0.10 per ton. Operating costs average $0.40 to $1.20 per ton, and total costs range from $0.44 to $1.30 per ton.

The cost of a 400-ton-per-day animal manure incineration plant is $450,000, which amortizes to $0.80 per ton. Operating costs average $1.20 per ton and total costs $2 per ton. Cost figures for cattle feedlot manure disposal by combustion are given in Table 31, which is based on the assumption that all liquid and gaseous effluents from the waste destruction processes must be treated (including nitrogen and phosphorous removal) and that there is no resource recovery. The solids handling system includes dewatering, incineration, offgas treatment, and biological treatment of the filtrate. The cost figures in Table 31 reflect higher capital investment but lower operating costs than quoted above because of more advanced effluent treatment and incinerator systems.

TABLE 31

COST OF CATTLE FEEDLOT MANURE DISPOSAL BY COMBUSTION

	Number of Animals				
	500	1000	5000	10000	25000
Total Capital Cost	198,000	251,700	402,200	741,760	1,351,400
Annual Amortization of Capital Cost	15,800	20,100	32,200	59,400	108,100
Annual Operating Cost	14,600	21,900	54,700	91,250	164,240
Total Annual Costs	30,400	42,000	86,900	150,650	272,340
Total Cost $/Ton of Manure	5.52	3.82	1.58	1.37	0.99

Source: From Okey, R.W., Rickles, R.N., Taylor, R.B., "Relative Economics of Animal Waste Disposal by Selected Wet and Dry Techniques," Animal Waste Management, the proceedings of the 1969 Cornell University Conference on Agricultural Waste Management.

Most well-operated combustion plants produce residues that vary from 5 to 25 percent by weight and 3 to 15 percent by volume of input wastes. Unburned combustible matter usually averages 2 to 7 percent by weight of the remaining residue. Thus the reduction of weight and volume of wastes by this process is very great.

This technology conserves no natural resources. However, the materials balance diagram, Figure 9, shows the output products from combustion of one ton of mixed municipal refuse in a conventional combustion plant.

In the case of high-temperature combustion, the residue is melted together in the form of a slag and is without resource recovery value.

Combustion of sewage sludge (or animal manure) yields only water and ash (Figure 10).

ii. Process Evaluation

Net Costs. As no resource is produced by this technology, no credits can be awarded to it. This technology must be looked upon as a base technology to which combustion with resource recovery can be compared.

Ratings:

Municipal waste:
  Conventional incineration ($8/ton): 4/8.
  High-temperature incineration ($10/ton): 2/8.
Sewage sludge ($0.44 to $1.30/ton): 8/8
Animal manure ($2/ton): 8/8.

Waste Reduction. This technology has the greatest efficiency in terms of volume and weight of waste reduction, leaving theoretically no combustible portions to be disposed of. In actual practice, some combustible material is left unburnt, but this is a negligible amount.

Rating: All waste streams: 8/8.

Flexibility. This technology can accept all waste streams and is not significantly affected by minor alterations in the waste composition. Incineration plants can be located anywhere and can easily assimilate new processes for extraction of resources.

Rating: For all waste streams: 8/8.

Figure 15-4!

FIGURE 9

MATERIALS BALANCE FOR COMBUSTION OF MUNICIPAL REFUSE

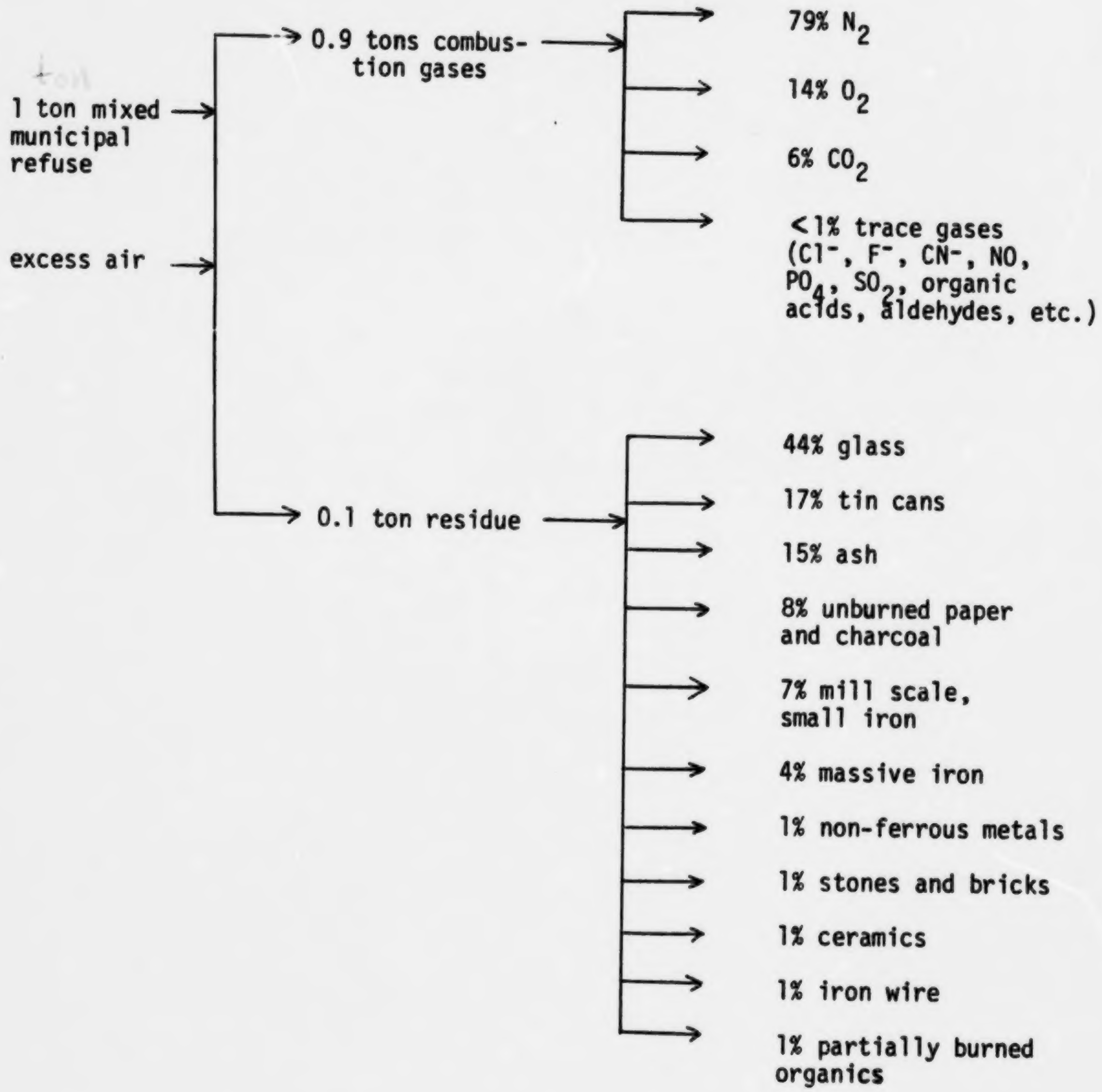
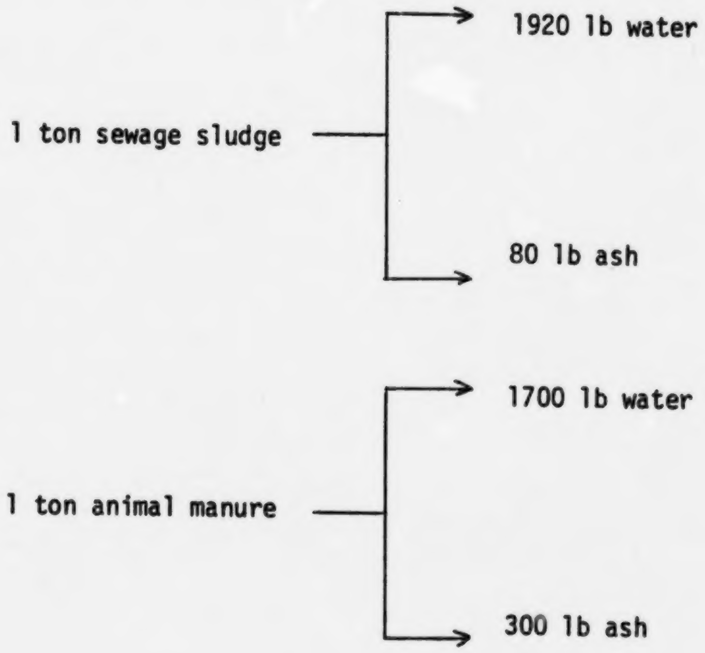

ton
1 ton mixed municipal refuse
excess air
0.9 tons combustion gases
79% N_2
14% O_2
6% CO_2
<1% trace gases (Cl^-, F^-, CN^-, NO, PO_4, SO_2, organic acids, aldehydes, etc.)
0.1 ton residue
44% glass
17% tin cans
15% ash
8% unburned paper and charcoal
7% mill scale, small iron
4% massive iron
1% non-ferrous metals
1% stones and bricks
1% ceramics
1% iron wire
1% partially burned organics

FIGURE 10

MATERIALS BALANCE FOR COMBUSTION OF SEWAGE SLUDGE AND ANIMAL MANURE



State of Development. Combustion processes have been in practice for a considerable amount of time and are constantly undergoing modification for improved efficiency. High-temperature combustion is, however, just emerging from the experimental state.

Rating: For all waste streams:
Conventional combustion: 8/8.
High-temperature combustion: 4/8.

Conservation of Natural Resources. Combustion without resource recovery conserves no natural resources.

Rating: 1/8.

Weighted Totals:

Municipal waste:
Conventional combustion:
4x33 + 8x28 + 8x12 + 8x19 + 1x8 = 612/800.
High-temperature combustion:
2x33 + 8x28 + 8x12 + 4x19 + 1x8 = 470/800.
Sewage sludge:
8x33 + 8x28 + 8x12 + 8x19 + 1x8 = 744/800.
Animal manure:
4x33 + 8x28 + 8x12 + 8x19 + 1x8 = 612/800.

b. Combustion to Produce Steam for Heating (and/or Cooling)

i. Process Description

Steam-generating incinerator plants consist of the basic conventional plant described in the previous section with the addition of a heat-exchange system. Steam is generated either by using waste-heat boilers in a refractory furnace, or by using water-walled furnaces for better heat-transfer efficiency. The steam, in turn, is either used to generate electricity or sold for space or process heat. Steam-generating refuse incineration plants in the United States have conventionally used refractory furnaces, drawing off the combustion gases into a waste-heat boiler. Waste-heat boilers draw gas through pipes or tubes with water in contact with the outside surface of the tubes. A more recent practice in the United States, and common practice in Europe, has been the use of the water-wall furnace.[30] The water-wall furnace consists of tubes installed in the walls of the primary combustion chamber, with water flowing through the tubes and heated by the combustion gases. The water-wall furnace has increased heat-transfer efficiency compared to a refractory furnace so that less excess air-cooling, only 50 to 60 percent, has to be introduced. Thus, smaller gas cleaning equipment can be used prior to discharge of incinerator emissions into the atmosphere. A number of such combustion plants are in operation in the United States and Europe.

The Chicago Northwest Incinerator,[31] the largest and newest such installation in the United States, is similar to the giant plants near Paris (the combustion plant at Ivry, France, is the world's largest refuse incinerator at a 2640-tons-per-day capacity).[32] It burns 1600 tons of shredded refuse per day in four water-wall furnaces of 400-tons-per-day capacity each. Part of the steam produced will be used to drive the plant's turbines producing electricity for on-site use. The remainder will be sold to commercial users of space heat. The boilers are of the welded water-wall type. Air pollution control consists of electrostatic precipitators. To ensure continued supply of steam to customers, two auxiliary gas burners have been installed in each of the four furnaces. Each burner has a capacity of 71,000 cubic feet of gas per hour and can produce 55,000 pounds of steam per hour.

.he waste reduction is similar to conventional combustion plants except that in most steam-generating combustion plants it has become the practice to remove ferrous metals prior to incineration.[33] This improves burning inside the combustion chamber to some extent.

Because of the comparatively lower heat values inherent in sewage sludge and animal manure, these waste streams seldom utilize this technology.

The flow diagram for this process appears in Figure 11.

Capital costs range from $12,000 to $16,000 per ton of daily rated capacity.

Operating and maintenance costs range from $3 to $20 per ton.

Total costs before credits range from $9 to $25 per ton.

Capital costs for a 400-ton-per-day plant for municipal refuse average to $5,400,000, which amortizes to $4.30 per ton. Operating costs average $6.20 per ton, and total costs $10.50 per ton, prior to credit for steam produced.

Detailed costs for the Chicago Northwest Incinerator reflect the costs described above (Table 32).

A high-temperature combustion plant at this scale costs $7,400,000, which amortizes to $6.40 per ton. Operating costs

FIGURE 11

FLOW DIAGRAM FOR A STEAM-GENERATING COMBUSTION PLANT

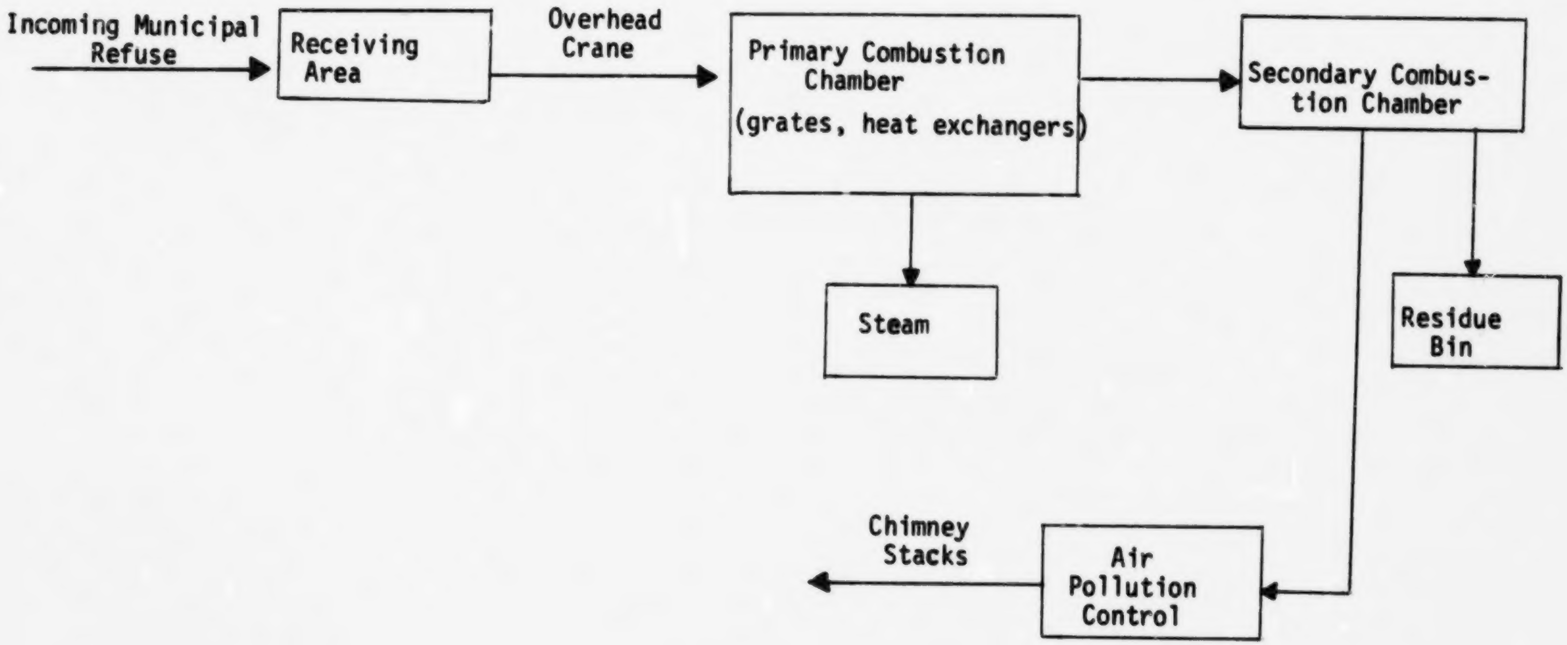

Incoming Municipal Refuse
Receiving Area
Overhead Crane
Primary Combustion Chamber (grates, heat exchangers)
Secondary Combustion Chamber
Steam
Residue Bin
Chimney Stacks
Air Pollution Control

TABLE 32

CHICAGO NORTHWEST INCINERATOR COSTS

1. Refuse Burning Systems	8,000,000
2. Electrostatic Precipitators	750,000
3. Concrete Substructure	2,500,000
4. Superstructure (Including Electrical, Plumbing)	5,500,000
5. Cranes	600,000
6. Bulk Refuse Shredders	500,000
7. Chimneys	600,000
8. Land, Site Clearance, Access Road, Garages, Maintenance Facilities, Engineering	4,500,000
	22,950,000
CAPITAL COSTS	23,000,000

Capacity of incinerator = 1600 tons/day
CAPITAL COSTS = $14,000 per ton/day

Amortized over 20 years at 6% = $3.80/ton
Operation of Maintenance Costs= 4.00/ton

TOTAL COSTS $7.80/ton

Source: Personal communication from William Ryder, Chief Design Engineer, Environmental Programs, Bureau of Engineering, Department of Public Works, City of Chicago, to Narayan Thadani, International Research & Technology Corporation.

are $5.60 per ton and total costs $12 per ton, prior to credit for steam produced.

Steam-generating incineration plants, being of more recent origin than most municipal plants, tend to use the most sophisticated equipment being used in conventional municipal combustion plants and hence have a basic cost structure as expensive as the most expensive conventional incinerators. In addition, steam-generating equipment adds another $2 per ton of input refuse to total costs.

The materials balance is similar to that for combustion without resource recovery, except that the combustion gases are now utilized in a heat exchanger such as to yield 1 to 3.5 lb of steam (= 2 lb steam average) for every pound of refuse.

ii. Marketing

Present and projected residential energy uses indicate that in the United States an average of 50 percent of this market is dominated by space heating.[34] At present this market is dominated by gas and oil (30 to 40 percent share each) with coal and electricity sharing approximately 10 percent of the market each. Considering the negligible amount of space heat energy available from refuse, this should not make a noticeable dent on markets or trends for other fuels. The physical limitations on the area over which space heating from steam as generated in refuse combustion plants will be the major restriction to complete utilization of this resource from waste.

The temperature and pressure at which the steam is generated in a refuse combustion plant also leave much to be desired from a distribution point of view. Conventional plants or boilers which produce steam for space heat do so at higher temperatures and pressures for more effective distribution.

iii. Evaluation

Net Costs. Steam production averages 2 pounds steam per pound of refuse. Steam can be sold for an average price of $1 per ton of steam, or $2 per ton of input refuse. Thus a credit of $2 may be taken for steam-generating combustion plants. Since this is the cost of the add-on equipment to a conventional combustion plant for producing steam, the net cost of combustion to produce steam for heating (and/or cooling) is about the same as that for a conventional combustion plant that experiences no resource recovery. However, steam-generating incinerators generally separate out ferrous metals from the municipal waste stream and take a credit of $1.33 per ton of refuse for this. The marketing and distribution costs for the steam and iron are estimated to average $0.84 per ton of refuse. Thus the net cost for a conventional combustion plant recovering steam for heating is $10.50 - $2.00 - $1.33 + $0.84 = $8.01 per ton. The comparative net cost of high-temperature combustion would be $12.00 - $1.33 - $2.00 + $0.50 = $9.17 per ton.

Ratings: for municipal wastes:
Conventional combustion ($8.01/ton): 4/8.
High-temperature combustion ($9.17/ton): 4/8.

Waste Reduction. This is similar to that for conventional combustion, except in this technology the noncombustible waste stream is usually also reduced as the ferrous metals are removed prior to combustion.

Rating: 8/8.

Flexibility. These plants must be located adjacent to or near customers who can utilize the steam. This is not always possible, although there is a trend now toward locating these plants in an urban or industrial environment conducive to the steam production levels from a refuse combustion plant. In all other aspects, the flexibility of these plants matches that of combustion without resource recovery.

Rating: 4/8.

State of Development. This is existing state-of-the-art technology with research in improved efficiency constantly ongoing.

Rating: 8/8.

Conservation of Natural Resources. Out of the 10^8 tons of municipal wastes available in concentrations able to support a 400-ton-per-day plant, 10^5 BTU of energy can be extracted per year. This is equal to 1.4 percent of all the energy used in the United States in 1970, and equal to 7.4 percent of the energy normally supplied by bituminous coal and lignite in 1970 (this is equal to $1/2 \times 10^8$ tons of coal and lignite per year).

Rating: 8/8.

Weighted Totals:

Conventional combustion to produce steam for heating (and/or cooling):

$4 \times 33 + 8 \times 28 + 4 \times 12 + 8 \times 19 + 8 \times 8 = 620/800.$

High-temperature combustion to produce steam for heating (and/or cooling):

$4 \times 33 + 8 \times 28 + 4 \times 12 + 4 \times 19 + 8 \times 8 = 544/800.$

c. Combustion to Produce Electricity

i. Process Description

There are two ways to generate electricity from municipal refuse: producing steam through a heat exchange using waste heat from the combustion process, and then using the steam to power a turbine; or using the waste combustion gases directly to power a gas turbine.

(a) Power generation from steam:

The plant required to generate electricity from refuse is basically the same as that for the incinerator with steam recovery discussed in the preceding section. It consists of a conventional incinerator, heat exchangers to produce steam from waste heat, and a steam turbine to produce electricity.

(b) Power generation from combustion gases:[35]

A combustion plant for this purpose must burn refuse in a high-pressure combustor to produce hot gases that can be used to power a gas turbine. In turn, the turbine drives an electric generator.

Although the production of electricity from steam is a well developed technology, particularly in European prototypes, the generation of power directly from combustion gases is a relatively novel technology. Only one pilot plant of 100 tons of refuse per day capacity is under development. The company developing the system suggests that larger units be constructed of several complete subunits of about the same size as the pilot plant. Thus a description of the pilot plant will serve as a description of the probable operation of any larger plants.

The 100-ton-per-day pilot plant consists of a solid waste subsystem where incoming municipal refuse is shred by two mills (75 and 100 hp) and air classified at a rate of 6 tons per hour to remove non-combustibles. The heavy fraction is passed through a system to separate metals and glass into categories suitable for recycling. The light fraction is then transported pneumatically to a 3,000-cubic-foot storage vessel (about 20-ton capacity) from which the shredded refuse is swept into a weighing conveyor and then into two rotary feeder valves used to deliver the solid waste fuel across the pressure interface into the combustor. Compressed air from the turbine compressor is used to supply transport air for the solid waste fuel, to fluidize the combustor sand bed, and to supply oxygen for combustion.

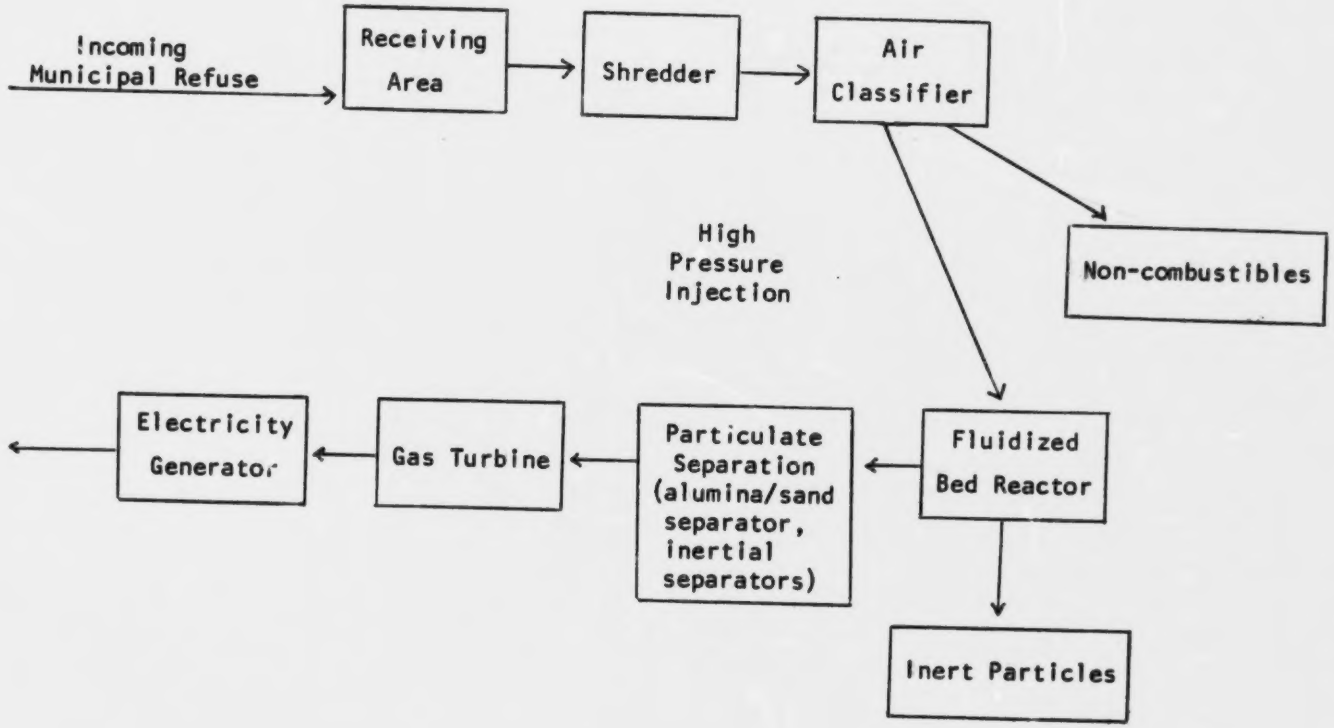
The solid waste is burned in a fluidized bed combustor, 10 feet outside diameter and 7 feet inside. It is 22 feet high. The combustor has an external mild steel pressure shell, and internal refractory lining. Temperature of the fluid bed during initial 48-hour continuous tests, running on refuse, ranged generally between 12[illegible] and 1350F while combustor outlet temperature was maintained between 1499 and 1519F. Carbon combustion efficiency was maintained at 99.8%.

The hot gas from the combustor passes through an alumina/sand separator and two stages of inertial separators to remove particulates. The cleaned hot gases are then expanded through a 1500 hp gas turbine that, under pilot plant conditions generates about 1,000 KW of electricity. The efficiency of the particulate separators is such that scouring of the turbine blades by particulate matter has not been evident.

A flow diagram for the production of electricity from combustion gases appears in Figure 12.

FIGURE 12

FLOW DIAGRAM FOR POWER GENERATION FROM COMBUSTION GASES



Costs

(a) Power generation from steam:

Capital costs appear to range from $14,000 to $23,000 per ton of daily rated capacity. Operating costs range from $3 to $20 per ton as capacity decreases from 4000 to 100 tons per day. Total costs range from $12 to $30 per ton as capacity decreases from 2500 to 100 tons per day.

Capital cost for a 400-ton-per-day plant would be $7,280,000, which amortizes to $6.40 per ton. Operating cost at this scale would be $7.10 per ton, and total costs $13.50 per ton, prior to credit for electricity produced.

(b) Power generation from combustion gases:

Costs are estimated here on the basis of data furnished by the one developer, but it may be too early in the development of this system for cost estimations to be reliable figures.

Capital cost for a 400 ton/day plant would be $6,000,000, which amortizes to $4.30. Operating cost would be $4.90/ton and total costs $9.20 ton, prior to credit for electricity produced.

Materials Balance

(a) Power generation from steam:

The materials balance is similar to that indicated for steam recovery above, except steam is now passed into a steam turbine to produce electricity. The power yield from municipal refuse is estimated as follows:

5000 BTU/lb = 1.5 Kwh/lb = 3000 Kwh/ton
assuming 20% efficiency in conversion to
electricity = 600 Kwh/ton;

or, 1 pound of refuse produces 1 to 3.5 pounds of steam (= 2 lb steam average). Five to eight pounds steam produces 1 Kwh (in high performance steam engines). Thus approximately 3 to 4 pounds of refuse should produce 1 Kwh of power yielding a production of 500 to 600 Kwh/ton of refuse, which agrees with the figure above.

(b) Power generation from combustion gases:

The materials balance is similar to combustion without resource recovery, except that the combustion gases are drawn directly into a gas turbine to produce electricity. The power yield is similar to that for power generation for steam (i.e., 600 Kwh/ton of refuse).

ii. Marketing

Electricity demands are projected to exceed 20 quadrillion BTU by 1980.[36] The 10^{15} BTU supplied by refuse could thus be easily absorbed into the total market for electricity. However, because of the small quantities of power produced at an individual refuse combustion plant, and the uncertainty of producing it on a continuously available basis, marketing electricity from this source to individual users may prove to be a serious problem. The most suitable customer would be a utility grid system which could accept power of this nature on the variable basis that seems to dominate at combustion plants.

iii. Evaluation

Net Costs. Equipment for generating electricity from steam will cost from 20 to 40 percent of the steam-generating plant cost. This will add another \$2 to \$3 per ton to the total cost of refuse processing. Assuming a conservative 500 Kwh per ton of refuse, the break-even point for the economic feasibility of generating power from refuse occurs when power can be sold for at least 6 mills per Kwh. Since energy rates range from 2.5 mills per Kwh to more than 10 mills per Kwh,[37] power generation from refuse must be localized according to regional economic feasibility and demand. At an average of 6 mills per Kwh and an electricity generation of 500 Kwh per ton of refuse, the electricity produced from refuse is worth a credit of .006x500 = \$3 per ton of refuse. Since the cost of the additional equipment for producing electricity from steam is \$3 per ton of refuse, the actual credit from electricity generation is zero dollars. Thus the net costs of this technology are: \$13.50 - \$3.00 = \$10.50 per ton.

In addition, the small quantities of electricity produced in a fairly large combustion plant would not be marketable on a regular basis to anyone but a utility grid system. Generating power for use within the plant may, however, be feasible.

Thus power generation from refuse appears economical only in areas with high electricity costs. At the average cost of electricity in the United States, power production is less remunerative than steam generation.

Costs and credits for electricity generation from combustion gases are still being developed, but following logic similar to that for power generation from steam and using some of the figures supplied by the sole developer of this system, the net costs should be $9.20 - $3.00 = $6.20 per ton.

Rating: For municipal solid wastes:
Power generation from steam (conventional refuse combustion plant): 4/8.
Power generation from combustion gases: 4/8.

Waste Reduction. This is similar to that for combustion to produce steam for heating (and/or cooling).

Rating: For municipal solid wastes:
Power generation from steam: 8/8.
Power generation from combustion gases: 8/8.

Flexibility. Electricity being a more easily distributable form of energy than steam, this process has somewhat greater flexibility than combustion to produce steam. However, it is subject to market fluctuations and the ability to locate users who can utilize small quantities of a non-storable fuel which is not supplied on a regular basis (because of the frequent breakdowns, operation and maintenance halts, and other inoperative periods associated with the majority of combustion plants).

Rating: For municipal solid wastes:
Power generation from steam: 4/8.
Power generation from combustion gases: 4/8.

State of Development. Power generation from steam from combustion of refuse is widely practiced in Europe and there are a few applications in the United States. Power generation from combustion gases released during the combustion of refuse is, however, in an experimental stage.

Rating: For municipal solid wastes:
Power generation from steam: 8/8.
Power generation from combustion gases: 1/8.

Conservation of Natural Resources. This is similar to combustion to produce steam in that 1.4 percent of U.S. energy requirements can be met.

Rating: For municipal solid wastes:
Power generation from steam: 8/8.
Power generation from combustion gases: 8/8.

Weighted Total:

Power generation from steam:
4x33 + 8x28 + 4x12 + 8x19 + 8x8 = 620/800.
Power generation from combustion gases:
4x33 + 8x28 + 4x12 + 1x19 + 8x8 = 487/800.

d. Combustion of Waste as a Fossil Fuel Substitute

i. Process Description

A facility to prepare municipal refuse and mix it with pulverized coal for the purpose of generating electricity in a conventional coal-burning power plant modified to accept the mixed fuel is presently under development.[38] The plant is expected to handle 300 tons per day of refuse. A conventional pulverized coal boiler will be fired with a 10 percent refuse and 90 percent coal mixture (based on heat value). For every ton of refuse used, three to four tons of coal will be introduced. The coal boiler is expected to be more efficient than a conventional municipal refuse incineration plant since the coal boiler operates at higher furnace temperatures with lower percentages of excess air. (Conventional incinerators require a considerable amount of excess air in order to maintain furnace temperatures well below 2000 degrees F to prevent excessive slagging.)

As presently envisioned, municipal refuse will be received and shredded (to a maximum particle size of 1.5 inches) on a two-shift operation at a transfer station from which transfer trailers will transport refuse to the power plant. Only magnetic materials will be removed at the transfer station. The remaining mixed shredded refuse will be pneumatically fed by means of tangential firing, to the boiler.

A flow diagram for the process appears in Figure 13.

The projected cost breakdown on the coal-refuse boiler plants indicates total processing costs range from $3 to $5 per ton of input refuse.

The capital cost for a 400-ton-per-day plant is expected to be approximately $3,000,000, which amortizes to $3.80 per ton. Operating costs are estimated to be $1.20 per ton, and total costs $5 per ton. These costs are yet to be proven in practice, however. The anticipated costs for a St. Louis coal-fired power plant processing one or two thousand tons of refuse are given in Table 33, and are seen to be in the vicinity of $5 per ton of waste.

The power yield for this system has not yet been determined, although the refuse contribution to power production should still average 600 Kwh per ton of refuse as with power generation from combustion gases.

ii. Marketing

The electric utility sector of primary energy consumers appears to be the market for which refuse as fuel is best suited. The utilities are projected to be the largest primary consumer of energy in 1980 and 1990,[39] and the refuse generated in all urban areas represents only 10 percent of the 1970 electric utility energy requirements,

FIGURE 13

FLOW DIAGRAM FOR THE COMBUSTION OF WASTE AS A FOSSIL FUEL SUBSTITUTE

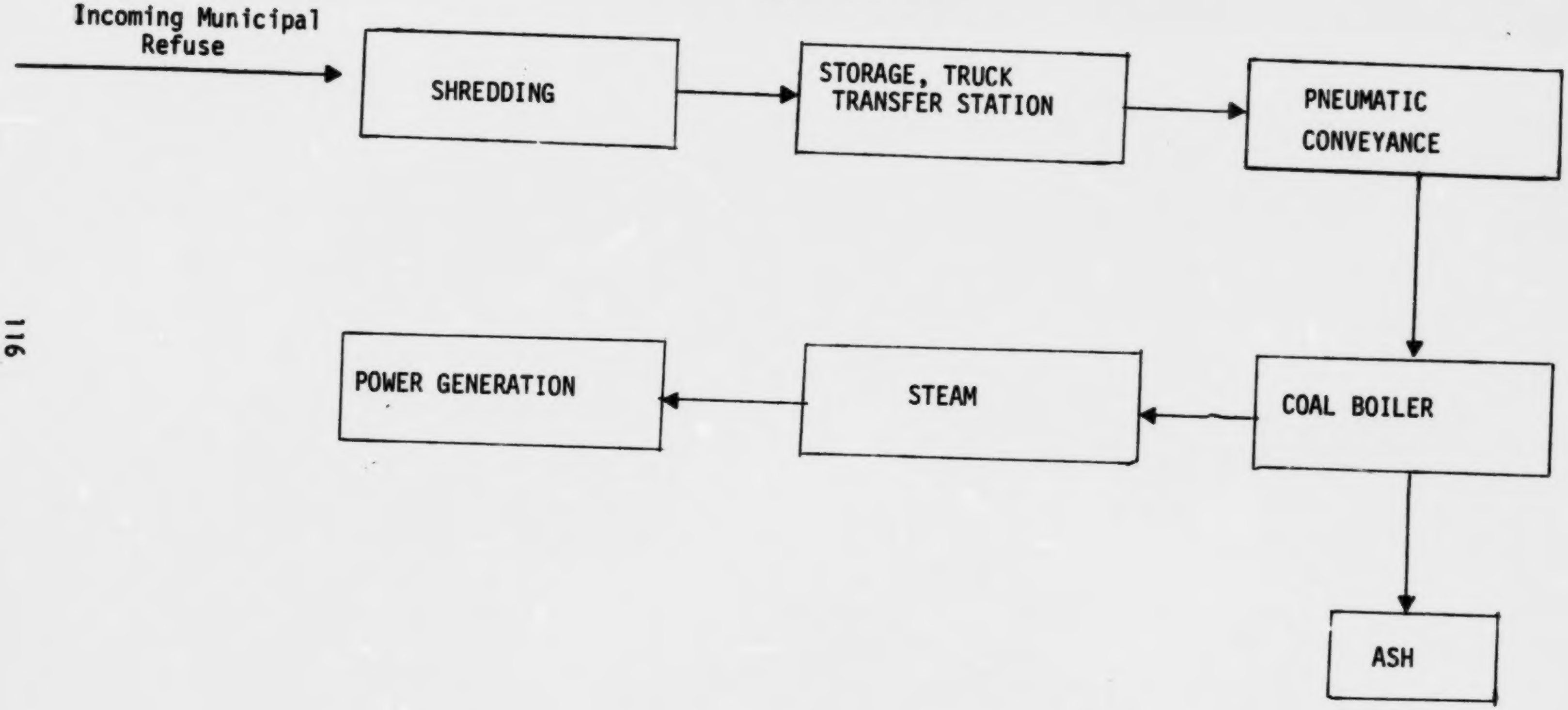


TABLE 33

ST. LOUIS POWER PLANT CAPITAL AND OPERATING COST SUMMARY

	One Processing Unit*	Two Processing Units*
Raw Refuse Processed		
Tons/day	980	1,960
Tons/year, 5-day operation	254,800	509,600
Tons/year, 6-day operation	305,760	611,520
Supplementary Fuel Produced		
Tons/day	906	1,812
Tons/year, 5-day operation	235,560	471,120
Tons/year, 5-day operation	282,672	565,344
Estimated Capital Costs (1973)		
Processing Facilities	3,427,000	6,432,000
Transporting Facilities	579,000	832,000
Receiving Facilities	232,000	456,000
Firing Facilities	973,000	1,060,000
Total Estimated Capital Cost	$ 5,211,000	$ 8,780,000
Estimated Annual Operation and Maintenance Costs (1973)		
Processing Plant	558,000	975,000
Transport Facilities	283,200	546,400
Receiving and Firing Facilities	55,700	75,000
Total Estimated Operation and Maintenance Costs--		
5 days/week operation	896,900	1,596,400
6 days/week operation	1,075,000	1,920,000
Amortization Costs (Annual)	418,000	704,000
Equivalent Unit Costs--5 days/week operation		
Total Unit Cost--per ton of raw refuse	$5.16	$4.52

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TABLE 33

ST. LOUIS POWER PLANT CAPITAL AND OPERATING COST SUMMARY

	One Processing Unit*	Two Processing Units*
Equivalent Unit Costs--5 days/week operation		
Total Unit Cost-per ton of supplementary fuel	$5.59	$4.89
Equivalent Unit Costs--6 days/week operation		
Total Unit Cost--per ton of raw refuse	4.89	4.29
Total Unit Cost--per ton of supplementary fuel	5.29	4.64

---

*Two-shift operation

Credits - each ton of refuse saves 1/4 ton of coal worth $1.38

Source: Wisely, R.F., G.W. Sutterfield, and D.L. Klumb. St. Louis power plant to burn city refuse. Civil Engineering-ASCE January 1971.

decreasing to 6 percent in 1990 so that electric utilities have the potential to readily consume all of the energy in the urban refuse generated. Other factors are that the utilities are relatively stable installations permitting establishment of long-term, reliable arrangements for refuse energy utilization, and are already of necessity somewhat public service oriented, making them susceptible to pressures other than economic to become involved in the utilization of refuse energy.

The use of refuse as a primary energy by firing prepared refuse directly in utility boilers as a supplement to other fuels places several limitations on the potential market for refuse as fuel for electric utilities. Initially the market is limited by the fact that the feasibility of successfully firing mixed municipal refuse in a high-capacity utility class boiler with no degradation in the performance and reliability of the boiler has not yet been demonstrated. While the technology for this appears to exist, actual practice is awaiting the results of a trial installation. Until proper operation has been successfully demonstrated, there is not likely to be a utility market for refuse as fuel due to the risks involved.

Assuming success in firing refuse directly in a utility boiler, the second limitation is imposed by the high ash content of refuse which at an average 26 percent by weight is comparable to that of coal.[40] The direct use of refuse as fuel would therefore be limited to boilers presently firing coal and others with ash handling equipment dating from past use of coal, as well as those boilers which might be equipped for ash handling. Assuming estimated coal utilization by electric utilities as a measure of the potential market for refuse as fuel, the heating value of refuse would represent 17 percent of the 1970 coal consumption by utilities, 23 percent of the 1980 consumption, and an estimated 25 percent of the 1990 consumption. Twenty-five percent is somewhat in excess of the 10-12 percent currently estimated as the maximum utilization of refuse as a supplemental fuel due to technical limitations. In addition, the distribution of coal-burning utility boilers throughout the country will not precisely match the locations of generation of urban refuse. These factors result in a likely surplus of urban refuse generation over that which can be absorbed by direct firing in suitable utility boilers, and necessitate the transportation, perhaps over significant distances, of much of the refuse to obtain access to the market represented by coal-burning utility boilers.

The price that refuse can command as fuel appears to be indeterminate at this time due to the potential market's reservations as to the technical consequences and resulting costs of using refuse as fuel. It does appear, however, that if the feasibility of utilizing refuse as fuel is demonstrated and if the applicable utilities can be influenced to fire refuse as fuel, refuse will command a price equivalent to the heating value of the fuel supplanted, most likely coal, against which must be set the amortization and operating costs of any equipment or changed operations necessitated by the use of refuse as fuel. In the opinion of the majority of the applicable utilities contacted, this balance will result in refuse having a net negative value as fuel, requiring a subsidy to support its utilization. The level of this subsidy was estimated by one utility to be $1 per ton of prepared delivered refuse, and was estimated by engineering calculations to be within a range from slightly better than break-even to as high as $8 per ton.

iii. Evaluation

Net Cost. The approximate total cost of managing a ton of waste by combustion with coal in a power plant $5. Municipal waste has a heat content of about ten million BTU per ton. Coal sells for $0.23 per million BTU, so refuse burned in a power plant should have a value of $2.30 per ton. Thus, the net cost of this process would be $5.00-$2.30 = $2.70 per ton of waste.

Rating: 8/8.

Waste Reduction. This is similar to that for other combustion technologies.

Rating: 8/8.

Flexibility. This is similar to the other combustion technologies except that it must be located wherever a power-generating facility is located, which is usually not an optimal location from a solid waste collection point of view.

Rating: 4/8.

State of Development. This technology is currently being demonstrated on a full-scale basis at the Meramec station of the Union Electric Company in St. Louis. At present the process appears hopeful, although minor modifications may be necessary.

Rating: 4/8.

Conservation of Natural Resources. This is similar to that for combustion to produce electricity in a conventional combustion plant.

Rating: 8/8.

Weighted Totals:

8x33 + 8x28 + 4x12 + 4x19 + 8x8 = 676/800.

2. Chemical Processes

a. Pyrolysis

i. Process Description

Pyrolysis,or destructive distillation, is a process in which a material is heated in the absence of oxygen to drive off volatile components and leave, at least for the materials under study, a char consisting mainly of carbon and a fairly large ash content. By varying the temperature and pressure of the pyrolysis, it is possible to vary the proportions of liquid or gaseous products driven off.

Our study concentrated on two commercial pyrolysis processes in advanced states of development, both of which have been demonstrated in pilot plants. One process recovers an oil similar to #6 oil and some char that could be a coal substitute. The second process is essentially a pyrolytic incinerator.

For the process which achieves some resource extraction, glass and metal would be separated out and recovered, and organic materials in the refuse converted to fuel. From one ton of as-received municipal refuse, one-fourth ton of low sulfur oil, and one-twentieth ton of low sulfur, but high ash, char is generated. About 40 percent (by weight) of dry organics in solid waste can be converted to oil. With modifications of the method, municipal refuse can be gasified to produce only gas fuel.

This pyrolysis process has been studied on a continuous feed, 4-ton-per-day pilot plant.

The system operates very slightly above atmospheric pressure with a maximum temperature of 1800 degrees F. For oil recovery, the temperature in the pyrolysis reactor is 1000 degrees F; for gas recovery it is 1400 degrees F.

The process is compatible with pre-pyrolysis recovery of ferrous metals, glass and aluminum when sorting technologies become available.

The treatment of solid waste by this pyrolysis method includes the following operations:

(a) Primary shredding of raw feed to minus 2 inches.

(b) Drying of the wet, shredded refuse. This reduces the moisture content from about 25 percent to 3 percent. The heat for this drying comes from the hot combustion gases derived from the pyrolysis.

(c) Air classification to remove inorganics. Eighty to ninety percent of the inorganics are removed. Therefore, the feed to the pyrolysis reactor contains roughly 4 percent inorganics. These inorganics end up as ash in the product char. The ash content of the char is about 20 to 50 percent.

(d) Secondary shredding to a nominal minus 24 mesh, or something less than 40 mils.

(e) Pyrolysis of organic material. The carbonaceous materials are heated rapidly by gas at 1800 degrees F. The pyrolyzed products leave the reactor at about 1000 degrees F.

(f) Collection of pyrolysis products. The char is removed by a series of cyclones. The hot char-free products are rapidly cooled to recover liquid products before thermal cracking can occur. A venturi quench system is used for this purpose.

(g) Recovery of glass and metals from inorganics.

A simplified block diagram of these operations is shown in Figure 14.

A materials and energy balance for the process is presented in Table 34.

TABLE 34

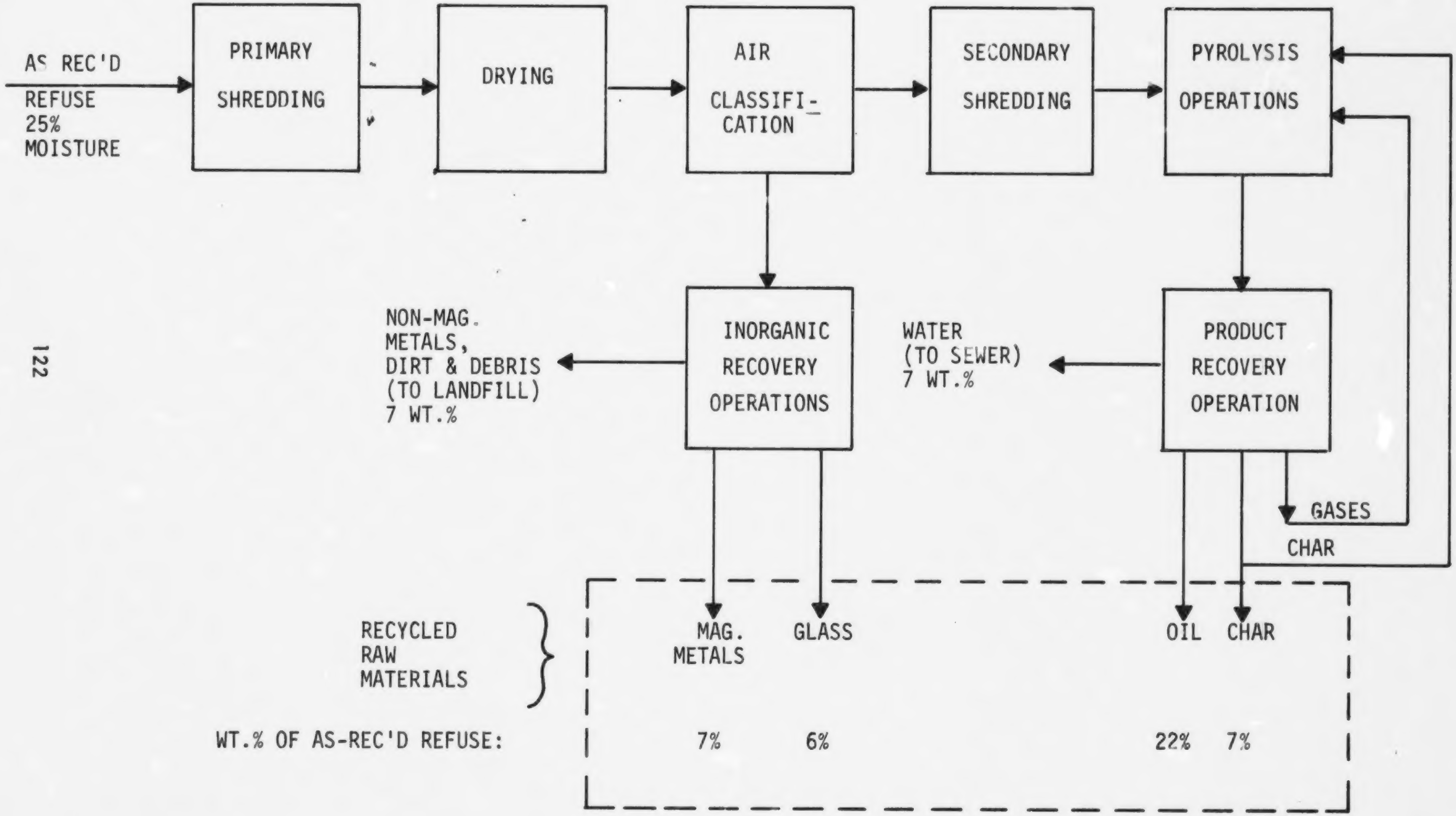
MATERIALS/ENERGY BALANCE FOR PYROLYSIS WITH RESOURCE EXTRACTION

Input	Output
One ton municipal waste	450 lbs oil (10,000 to 14,700 BTU/lb) 100 lbs char (6,000 to 12,000 BTU/lb) 660 lbs water 160 lbs glass 140 lbs ferrous metals 140 lbs "other inorganic waste"

The oil product contains organic acids. According to the system developer, this product is only slightly corrosive at ambient temperature. However, the oil will attack mild steel at 200 degrees F. Therefore, it should be stored in plastic-coated carbon steel, or other resistant materials. The developer also

FIGURE 14

FLOW DIAGRAM FOR THE PYROLYSIS OF MUNICIPAL WASTE WITH RESOURCE EXTRACTION



reports that when the oil is burned, the presence of organic acids poses no problems under conditions of complete combustion. Tests by two electric utility companies indicated that standard combustion equipment can be used with this oil, although separate storage and reticulation facilities would be needed.

The combustible gases derived from pyrolysis are totally consumed as fuel for the process heater. These gases have a heating value of 600 BTU per cubic foot. Two-thirds of the char is consumed in the heater prior to the pyrolysis reactor.

Sample plant economics for a 50-ton-per-day demonstration plant and a full-scale 2000-ton-per-day plant are shown in Tables 35 and 36 as they were derived by the system developer.

TABLE 35

SUMMARY OF ESTIMATED ECONOMICS FOR
50 TPD DEMONSTRATION PYROLYSIS PLANT

Basis:	50 TPD, 335 days/year		
	Refuse handling & preparation		- 1 shift/day
	Pyrolysis operations		- 3 shifts/day
	Moisture content		- 25%
	Self contained operation		
	Single train operation		
	Approximately 1000 degrees F		
	Atmospheric pressures		
	No hydrogenation required		
Total Capital Costs (excluding land)			$1,643,600
Total Annual Operating Costs			546,500
Operating Cost per Ton			32.63
	A. Feed preparation	$ 5.29	
	B. Pyrolysis operation	17.45	
	C. Offsites, admin. staff, O.H.	10.42	
Estimated Revenue from Sales			None
Annual Operating Cost of Demonstration Operation =			$225,000
	Operating Cost per Ton		$ 13.43

Note: Demonstration Operation assumes that the demonstration plant is located on an existing landfill site, and that some of the refuse handling and shredding operations, and all of the administration and staff engineering functions are performed by personnel currently available within the Sanitation Department.

TABLE 36

SUMMARY OF ESTIMATED ECONOMICS FOR 2,000 TPD SOLID WASTE PYROLYSIS PLANT

Basis: 2,000 TPD, Dual-Train, 24 Hours/Day
25% Moisture

Products: Pyrolysis Products
Magnetic Metals
Glass

Total Plant Capital Costs (excluding land)		$12,362,000
Working Capital		400,000
Annual Operating Costs		4,040,500
Annual Net Revenue from Sales		4,004,000
Annual Operating Debit		36,500
Costs per Ton:		
Plant Operating Costs (365 days/year)		$ 4.95
A. Feed Preparation	$1.88	
B. Glass Recovery	0.30	
C. Pyrolysis Process	2.60	
D. Offsites, Admin. and O.H.	0.75	
*Total operating costs calculated to 350 day/year basis		5.16
Net revenue from sales after residual disposal cost of $0.12 (350 days/year)		5.72
Operating debit		.56
Credit for elimination of disposal costs		$2.50 to $13.00 per ton

---

*Pyrolysis operation shutdown for maintenance 15 days per year; alternate disposal site must be utilized, but plant staff is available for shredding and landfill operation if required.

This pyrolysis process may also be used on manure to extract a #6 type oil. The equipment used and the processes are virtually identical to those described for municipal waste treatment except that feed preparation is less elaborate. The manure must first have its moisture content reduced to 45 percent from 85 percent. This can be done either by letting it dry naturally or by actively drying it. Actively drying it will add $1 to $2 per wet ton to the costs.

The yields from a ton of wet manure (85 percent water) are expected to be:

Oil:	12,000 BTU/lb	0.072 ton/wet ton
Char:	11,000 BTU/lb	0.027 ton/wet ton
Gas:	500 BTU/s.c.f.	0.036 ton/wet ton (all gas used for process heat)

In the other pyrolysis method, waste is shredded and then fed into a rotating kiln where the pyrolysis occurs in an oxygen-deficient atmosphere. The combustible materials are decomposed to gases and inert residues. The remaining residue will be about 6 percent of the original refuse.

In brief, the treatment of solid waste by this system includes the following operations:

(a) Shredding of the refuse.

(b) Pyrolysis of the shredded refuse. Pyrolysis is done in a rotating refractory-lined kiln. The waste is decomposed into gaseous products, carbon and ash.

(c) Separation of ferrous metals. The hot residue is cooled before leaving the kiln and conveyed to a magnetic separator for removal of iron and steel. The residue is disposed of.

(d) Purification of gases. In order to destroy organic odor, the pyrolysis gases are fed into a refractory-lined gas purifier and burned.

(e) Scrubbing the gases. The exhaust gases are passed through a scrubbing tower where a water spray cools them and removes particulate matter. Figure 15 shows a commercial plant flow sheet. Tables 37 and 38 indicate residue, afterburner exit, and stack gas analyses. Economic evaluation by the system developer for a 1,000 TPD commercial plant is given in Table 39.

A 35-ton-per-day demonstration plant has been in operation for two years processing municipal wastes. The design of this system has not yet been adapted to animal manure.

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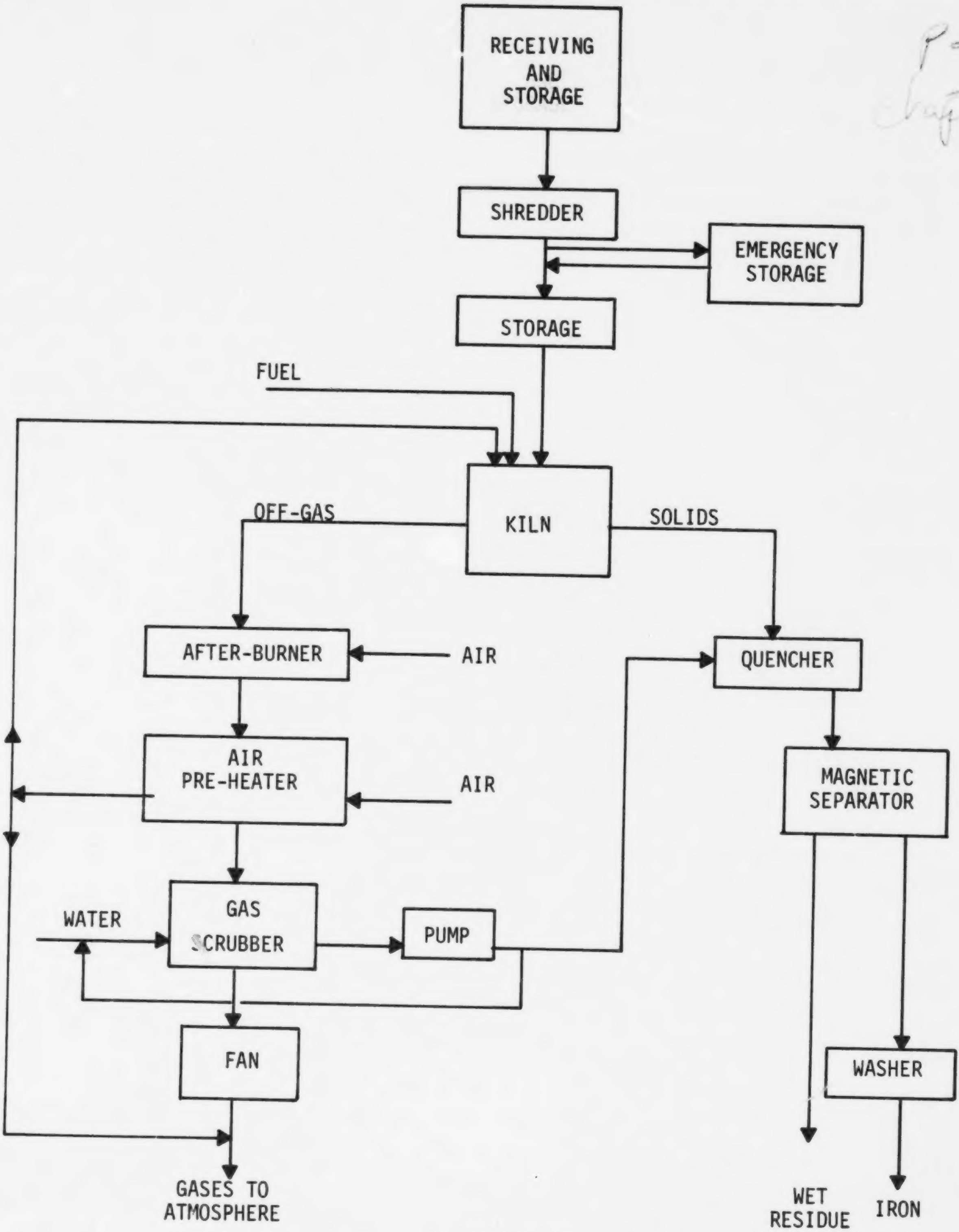

FIGURE 15

COMMERCIAL PLANT FLOW SHEET FOR PYROLYSIS OF MUNICIPAL SOLID WASTES WITHOUT RESOURCE EXTRACTION

TABLE 37

RESIDUE ANALYSIS FOR PYROLYSIS SYSTEM WITHOUT RESOURCE EXTRACTION

(Wt % Dry Basis)

Proximate Analysis		Ultimate Analysis	
Volatiles	7	Metal	18
Fixed Carbon	16	Glass	34
Inerts	77	Ash	25
		Carbon	19
		Sulfur	0.1
		Hydrogen	1
		Nitrogen	0.3
		Oxygen	3

Higher Heating Value = 2500 BTU/lb

pH = 12.0

Water Soluble Solids	2%
Putrescibles	< 0.1%

Source: From Monsanto Landgard System, St. Louis, Missouri.

TABLE 38

AFTERBURNER EXIT AND STACK GAS ANALYSES FOR PYROLYSIS SYSTEM WITHOUT RESOURCE EXTRACTION

	Afterburner Exit Gas Analysis Volume	Stack Gas Analysis Volume (Corrected for No Quench Air)
Nitrogen	65.4%	78.7%
Carbon Dioxide	11.4%	13.8%
Water Vapor	18.5%	1.8%
Oxygen	4.7%	5.7%
Hydrocarbons	< 10 ppm	< 10 ppm
Sulfur Dioxide	< 300 ppm	< 300 ppm
Nitrogen Oxides	< 80 ppm	< 80 ppm
Chlorides	< 200 ppm	< 25 ppm
Particulates (NAPCA method)	< 0.2 grains/scf dry gas corr. to 12% CO_2	< 0.02 grains/scf dry gas corr. to 12% CO_2

Source: From Monsanto Landgaro Systems, St. Louis, Missouri.

TABLE 39

ESTIMATED ECONOMICS FOR 1000 TPD SOLID WASTE PYROLYSIS DISPOSAL SYSTEM

Annual Operating Costs	
Amortization and interest (25 years at 6%)	$ 953,600
Electric power 1¢/Kwh	170,500
Fuel 40¢/10^6 BTU	155,000
Water $1/1000G	200,000
Manpower $4.5/man-hr	749,000
Maintenance	400,000
Miscellaneous	100,000
Total Annual Operating Cost	$ 2,728,100
Cost per ton	$8.8
Capital Costs	
Total Installed Cost	10,600,000
Contingency at 15%	1,590,000
Total Plant Cost	12,190,000
Working Capital	171,700
Total Estimated Capital Cost (excluding land)	$12,361,700

Source: From Monsanto Landgaro Systems, St. Louis, Missouri.

ii. The Markets for Fuel Oil and Char Produced from Combustible Waste

The oil produced from animal manure or municipal refuse will substitute for #6 fuel oil. Sales of #6 fuel oil in the United States reached 796,587,000 barrels in 1970. Based on population and energy demand forecasts and assuming that seasonal demand as a fraction of total petroleum demand will remain constant, the 1980 demand for #6 residual will be 1,234,709,850 barrels; the 1990 demand will be 1,656,900,960 barrels. Table 40 shows the current domestic markets for residual fuel oil in the United States.

Electric utilities used approximately 40 percent of the residual oil in 1970. Because delivery was made directly to the plants or as close to them as possible, the utilities enjoyed low prices ranging from $1.83 per barrel in the Mountain States to a relative high of $3.85 per barrel in the East North Central States. For the United States exclusive of Alaska and Hawaii, the price per barrel averaged $2.45. Costs figures were not available. An analysis of the probable cost per average barrel was undertaken which indicated that the oil cost was about $1.77 before it was shipped, with the difference of $0.68 going for transportation and other charges. An approximate accounting indicates the following breakdown of average price:

Cost of production	$1.77
Transportation and marketing	.32
Profit	.36
	$2.45

In contrast with the electric utilities, average prices for all #6 residual sold in the United States was $5.57 per barrel as of October 1971 (compared with $3.40 in July 1969). These higher prices include the retail price of oil sold to smaller consumers.

The breakdown is as follows:

Estimated refining price (average)	$2.76
Estimated freight costs (average)	1.12
Selling and administrative expenses	.55
Other expenses	.96
Net profit before taxes	.18
	$5.57

(Source: Derived from Annual Statement Studies, 1971, Robert Morris, Associates.)

The charcoal markets studied were those presently existing: charcoal used as a fuel for outdoor cooking and activated carbon used as a filter medium for water purification. The study did not attempt to evaluate the potential market for charcoal as a substitute

TABLE 40

SALES OF RESIDUAL FUEL OIL[a] BY USE IN THE UNITED STATES 1966-1970 (Thousand Barrels)

Use	1966	1967	1968	1969	1970
Heating	167,471	175,990	174,326	178,095	186,575
Industrial (excluding oil company use)	141,050	131,819	135,664	133,754[b]	137,634
Oil Company Use	35,177	37,880	39,329	36,559	38,987
Electric Utility Companies	140,642	158,417	184,956	247,634	309,010[b]
Railroads	3,792	5,494	4,296	3,381	2,222
Vessels	73,641	80,680	87,575	83,481[b]	86,650
Military	41,861	40,465	34,990	31,750	28,204
All Other	10,338	8,794	8,348	7,875[b]	7,295
United States, Total	613,972	639,539	669,484	722,529	796,587[b]

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[a] Includes Navy grade and crude oil burned as fuel.

[b] Revised.

Source: Mineral Industry Surveys, 1970, U.S. Bureau of Mines.

for coal in the production of electric power. (This latter market, however, may readily be extrapolated from the market study of refuse as fuel included in Section B1 above on Combustion Technologies.)

The properties of charcoal derived from solid municipal waste vary considerably with the material chosen for pyrolysis and the temperature of pyrolysis. Weight percent charcoal yield varies from 6.5 percent to a reported high of 49.8 percent for selected municipal wastes. Heating value of the resulting charcoal may vary from 6,000 BTU/lb to 12,000 BTU/lb. No quality standards are established by the charcoal industry which would permit a concise specification of charcoal and its properties or which would establish various grades of charcoal.

Based on an industry estimate (January 1972) of 8 to 13 percent compounded per annum growth, charcoal consumption may be placed at 1.25 billion pounds in 1971, 2.5 billion to 3.8 billion pounds in 1980, and 5.4 billion to 12.7 billion pounds in 1990.

Present wholesale prices vary between 5¢ and 6¢ per pound. Charcoal consumption, principally for home cooking, can be expected to increase if the market price is lowered. One producer estimates that a 20 percent increase in consumption would result from a 20 percent decrease in price.

A significant market for activated carbon derivable from solid municipal waste potentially exists in the secondary and tertiary treatment of municipal sewage. If current treatment technology were used, the activated carbon requirements for tertiary treatment of all municipal sewage would be approximately 50 billion pounds, while yearly replacement, assuming regeneration of spent carbon, would require approximately 3.8 billion pounds. For secondary treatment, the requirements would be approximately 240 billion pounds and replacement would require approximately 18 billion pounds annually (see Table 41). The price of activated carbon for waste water treatment ranges between 27¢ and 35¢ per pound. However, the high cost of this type of treatment renders this potential market a highly speculative one.

iii. Evaluation

The pyrolysis processes for resource extraction and for mere disposal were both evaluated for application to municipal waste, and the former was evaluated for application to animal manure.

Net Cost. The value of the resources recovered from a ton of municipal refuse is $5.72, as tabulated in Table 42. The most valuable resource is the oil, returning $3.50 per ton of refuse.

TABLE 41

PRESENT AND PROJECTED DEMAND FOR CHARCOAL AND ACTIVATED CARBON DERIVED FROM SOLID MUNICIPAL WASTE

	Demand (Billion Pounds)		
	1970	1980	1990
Potential from pyrolysis of solid municipal waste	26.7 to 85.5	30.8 to 98.6	36.0 to 115
Potential charcoal consumption (8 to 13% cmpd. per year from 1971)	1.2 to 1.3[a]	2.5 to 3.8	5.4 to 12.7
Activated carbon for sewage treatment potential			
Secondary Treatment			
Requirement	89.8	103.5	121.5
Replacement assuming regeneration[b]	6.7	7.7	9.1
Tertiary Treatment			
Requirement	18.7	21.6	25.3
Replacement assuming regeneration[b]	1.4	1.6	1.9

[a] As of 1971, 1980 and 1990 projections based on the average, 1.25 billion pounds.

[b] Assuming 7.5% replacement upon regeneration.

TABLE 42

PYROLYSIS WITH RESOURCE EXTRACTION--ESTIMATED REVENUE PER TON OF AS-RECEIVED REFUSE (25% MOISTURE)

Recovered Commodities	Wt. % of As-Received Refuse (Approx.)	% Avail. for Disposal	Commodity Value $/Ton	Estimated Revenue $/Ton Refuse
Magnetic Metals	7	95	20.00	1.33
Glass	8	70	14.00	0.78
Oil at ≃10,600 BTU/lb	24[a]	95	15.35	3.50
Char at ≃9,000 BUT/lb	15	34[b]	4.50	0.23
Gas at ≃600 BTU/ft^3	6	0[b]	4.00	0.00
Water	33	34[c]	-0.25	-0.03
Inorganic Wastes[d]	7	85	-1.50	-0.09
	Net Revenue per Ton of Refuse			5.72

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[a] Based on present oil yield of 40% per ton of dry refuse where 90% of inorganics have been removed prior to pyrolysis. Oil conversion may exceed 50% in future operations.

[b] About two-thirds of the char and all of the gas produced is used for process heat.

[c] Only the water from pyrolysis is collected and must be handled by conventional disposal methods. The 25% unbound moisture in refuse is removed in a dryer and then passed through the process heater to oxidize residual odors.

[d] Primarily non-ferrous metals, dirt and some glass which could have a potential sales value at a later date.

The char does not contribute significantly to the overall economics as a return of only about 0.2¢ per pound is anticipated on a large scale because of the limited market.

From the available data, we interpolate a processing cost per ton of refuse in a 400-ton-per-day plant of $8.75, to which should be added an approximate marketing and distribution cost of $1.45. Thus the net cost is $8.70 + $1.45 - $5.72 = $4.43.

The net cost of operating the pyrolysis system designed for waste disposal only is $12.60 per ton of refuse in a 400-ton-per-day plant.

The cost of pyrolyzing and extracting fuel oil and char from one ton of fresh cattle manure (85 percent moisture) in a 100-ton-per-day plant is $2.00. The process yields 144 pounds of oil that would have a value of $1.08 and 54 pounds of char with a value of $0.11, but the approximate cost of marketing these resources would be $0.30. Thus the net cost would be $2 + $0.30 - $1.19 = $1.11.

Ratings:
Pyrolysis of municipal waste with resource extraction: 8/8.
Pyrolysis of municipal waste without resource extraction: 2/8.
Pyrolysis of animal manure with resource extraction: 8/8.

Waste Reduction. The application of pyrolysis with resource extraction to municipal waste will not be limited by the size of the market for the main resource product--fuel oil. Thus the entire waste stream may be absorbed and the quantity of residuals will vary from 0.07 to 0.22 tons per ton of waste, depending on the possibilities for marketing the char, glass and ferrous metals. The residual ash from the application of pyrolysis without resource extraction amounts to 0.22 tons per ton of waste.

Similarly, with the pyrolysis of animal manure, the market for the major resource is not limiting, and the residual ash is only a small fraction of the input manure.

Ratings:
Pyrolysis of municipal waste with resource extraction: 8/8.
Pyrolysis of municipal waste without resource extraction: 8/8.
Pyrolysis of animal manure with resource extraction: 8/8.

Flexibility. The pyrolysis process proves desirable in terms of all factors used to evaluate flexibility. The resources generated by pyrolysis, namely low sulfur fuels in a conventional form, do not have to be consumed immediately. Both the char and the oil are storable by currently available means. Because of the magnitude of the market for energy in the United States, even if all combustible wastes that accumulate in sufficient quantity to support 400-ton-per-day units were pyrolyzed, the energy market could absorb the fuels produced with only very slight perturbation.

Ratings:
- Pyrolysis of municipal waste with resource extraction: 8/8.
- Pyrolysis of municipal waste without resource extraction: 8/8.
- Pyrolysis of animal manure with resource extraction: 8/8.

State of Development. A 4-ton-per-day pyrolysis with resource recovery pilot plant is in operation. A 35-ton-per-day pyrolysis without resource recovery plant is also in operation. The technologies could be available in less than five years. The organic acids in the oil may slow down introduction.

Ratings:
- Pyrolysis of municipal waste with resource extraction: 4/8.
- Pyrolysis of municipal waste without resource extraction: 4/8.
- Pyrolysis of animal manure with resource extraction: 4/8.

Conservation of Natural Resources. From municipal waste it would be possible to derive 28.6×10^6 tons per year of #6 oil. This is equal to 24 percent of current consumption of #6 oil. If the char may be considered as a coal substitute, the 9.1×10^6 tons that may be produced annually would be equivalent to 3 percent of the lignite and bituminous coal used for power generation.

From animal manure it would be possible to extract 5.6 percent of current #6 oil consumption and the equivalent of about 1 percent of the coal and lignite used by utilities.

Ratings:
- Pyrolysis of municipal waste with resource extraction: 4/8.
- Pyrolysis of municipal waste without resource extraction: 1/8.
- Pyrolysis of animal manure with resource extraction: 8/8.

Weighted Totals:

Pyrolysis of municipal waste with resource extraction:
8x33 + 8x28 + 8x12 + 4x19 + 4x8 = 692/800.
Pyrolysis of municipal waste without resource extraction:
2x33 + 8x28 + 8x12 + 4x19 + 1x8 = 470/800.
Pyrolysis of animal manure with resource extraction:
8x33 + 8x28 + 8x12 + 4x19 + 8x8 = 724/800.

b. Production of Ethanol and Hydrolytic Glucose

i. Process Description

The celluloses present in combustible waste materials may be hydrolyzed by dilute acid to yield hexoses and pentoses which may have value as food or feed or can be fermented by yeast strains to produce ethyl alcohol. Alcoholic fermentation is more widely known and more generally practiced than any other microbial technology. It is primarily practical in the production of alcoholic beverages; however, a small amount (less than 2 percent in 1966) of the ethanol used in non-beverage industries is produced by fermentation of the sugars in sulfite waste liquor and cheese whey. Most industrial ethanol is now produced from ethylene gas or ethyl sulfate at lower costs than fermentation of molasses sugars, which was the standard method of production of ethanol prior to World War II. However, if waste cellulose can provide low-cost or negative-cost sugars, fermentation may again become an economical means of ethanol production. We include discussion of this technology in the "Chemical Processes" section because the hydrolysis process would be the only relatively novel step in a refuse hydrolysis/fermentation plant.

The quantity of waste cellulose available and the potential amount of alcohol generated can be estimated. Municipal solid waste generated at a rate of 3.85 pounds dry weight per person-day presently averages 60 percent paper content. If 75 percent of the paper is considered available cellulose, the rest being filler and lignin or lignin-blocked cellulose,[42] then 0.75 x 0.60 x 3.85 = 1.75 pounds of available cellulose are generated per person-day. Manure from livestock, particularly cattle, also has a high cellulose content in undigested fibers. One cow producing 10 pounds dry weight of manure per day could contribute about 4 pounds of alpha and hemicellulose per day (this amount would be considerably influenced by the diet).

Complete hydrolysis of available cellulose would yield 112 percent sugars by weight:

$$C_6H_{10}O_5 + H_2O \rightleftharpoons C_6H_{12}O_6$$

However, with sulfuric acid catalyst, hydrolysis reaction conditions also favor sugar decomposition, and the maximum yield of sugars expected is 53 percent[43] or 59.4 percent of the weight of the available cellulose. Thus we can extract from wastes 1.04 pounds of sugar per person-day (381 pounds per person-year) or 2.35 pounds of sugar per cow-day (867 pounds per cow-year).

When the sugar is fermented,

$$C_6H_{12}O_6 \rightleftharpoons 2C_2H_5OH + 2CO_2$$

the weight of the alcohol produced can potentially be 51 percent of the weight of the sugar. However, in fermentation tests with Saccharomyces cervisiae thriving in hydrolyzed refuse the highest yield obtained was 94 percent.[44] Thus our potential ethanol resources are .51 x .94 x 381 = 182 pounds per person-year (24.8 gallons per person-year) and .51 x .94 x 867 = 416 pounds per cow-year (56.7 gallons per cow-year).

The costs of ethanol production from wastes can be broken down into costs arising from preparation of the wastes for processing, hydrolysis of the cellulose and fermentation of the sugars. If the cellulose in municipal refuse is chosen as the raw material, the wastes as received will be a mix of paper, metal, plastics, glass and wood. To extract the cellulose, the refuse would have to be ground at a cost of about $1 per ton and then the light cellulosic fraction separated by air classification or flotation for another $1 per ton of refuse. Cattle manure and fibrous crop residues, however, could probably be accepted by the hydrolysis operation as collected, or with some chopping.

When ethanol was chiefly produced from molasses, the cost of the sugars in molasses was the major production cost. Similarly, with waste cellulose the major cost of ethanol production is incurred in the hydrolysis to yield sugar. Porteus and Converse, et al., have estimated this cost for an ethanol plant, and Meller[45] has estimated the cost for the same hydrolysis as it arises in the conversion of refuse into yeast cells. Meller and Converse, et al., provide the most current and complete data. Meller found that a three-stage continuous process was more economical than a batch process or two- or four-stage continuous processes. Part of his costs were estimated from data from a manufacturer of equipment for pulping waste paper and separating reusable cellulose fibers. Meller took the capital and operating costs of an 80-ton-per-day (of waste paper) reactor (see Tables 43 through 46) and projected costs for larger plants using a cost exponent of 0.70. Meller's manufacturing costs include the purchase of waste paper for $13 per ton. For our purposes this should be replaced with grinding and separation costs of $2 per ton of refuse or $4.75 per ton of waste paper if the dry weight of waste paper is 42 percent of the refuse. Furthermore, a representative disposal cost of $2.50 per ton should

TABLE 43

ESTIMATE OF TOTAL CAPITAL INVESTMENT FOR CONTINUOUS PROCESS USING A THREE-STAGE REACTOR SYSTEM FOR HYDROLYSIS OF WASTE PAPER

Item & Basis of Estimation	Cost (CE = 109)
1. Purchased Equipment - Delivered (P.E.C.)	407,000
2. Equipment Installation (Including Instrumentation and Insulation) - 43% (P.E.C.)	175,000
Installed Equipment Cost	582,000
3. Piping (Including Insulation) - 36% (P.E.C.)	146,700
4. Electrical Installations - 15% (P.E.C.)	61,000
5. Buildings Including Services - 35% (P.E.C.)	142,600
6. Yard Improvements - 10% (P.E.C.)	40,700
7. Service Facilities - 35% (P.E.C.)	142,600
8. Land - 4.8% (P.E.C.)	19,500
Total Physical Plant Cost	1,135,100
9. Engineering and Construction - 40% (P.E.C.)	162,900
Direct Plant Cost (D.P.C.)	1,298,000
10. Contractors Fee - 7% (D.P.C.)	90,900
11. Contingency - 15 % (D.P.C.)	194,600
Fixed Capital Investment (F.C.I.)	1,583,500
12. Working Capital (Total Operating Cost for 30 Days)	104,000
Total Capital Investment	1,687,500

Note: 1967 cost figures.
Plant designed to treat 190 tons of refuse containing 80 dry tons of paper.

Source: From Meller, F.H. "Conversion of Organic Solid Wastes into Yeast - An Economic Evaluation," U.S. Environmental Protection Agency, Rockville, Md., 1969.

TABLE 44

FIXED CAPITAL INVESTMENT VS. PLANT SIZE FOR HYDROLYSIS OF WASTE PAPER

Capacity (Tons Feed Per Day)	Fixed Capital Investment (Chem Eng Index = 109)
80	$ 1,583,000
150	$ 2,460,000
300	$ 3,990,000
500	$ 5,720,000
1000	$ 9,260,000

Source: From Meller, F.H., "Conversion of Organic Solid Wastes into Yeast - An Economic Evaluation," U.S. Environmental Protection Agency, Rockville, Md., 1969.

be charged for unutilized noncellulosics at 40 percent of the refuse and unhydrolyzed lignin or cellulose at 15 percent of the refuse--together a charge of $1.38 per ton of refuse. Making these additions to Meller's data, Table 47 is derived.

Converse, et al., have also calculated expected costs for a hydrolysis plant receiving refuse with 60 percent paper content, basing their calculations on a single-stage continuous flow reactor with recycle capabilities. Costing procedure was broken into three primary stages of operations: (1) separation and pretreatment, (2) hydrolysis and recycle, and (3) neutralization and concentration to 12 percent sugar. The cost taken for the first stage is that of a commercial wet-handling system that removes all metals, glass and sand and disintegrates all the pulpable and grindable material creating a water slurry with a 50 percent moisture content. The cost of this pretreatment ranges from $7.50 per ton for a 175-ton-per-day plant to $2.80 per ton for a 1000-ton-per-day plant. The total capital investment for a 1000-ton-per-day plant is $4 million (1971). The operating cost includes a charge of $2.50 per ton for disposal of a residue.

The total cost for production (1971), including capital recovery, of sugars from refuse containing 60 percent cellulose, a reactor residence time of 15 seconds and solid/liquid ratio of reactor feed of 0.3 calculated for three plant sizes are:

250 T/D	500 T/D	1000 T/D
2.4¢/pound	1.9¢/pound	1.65¢/pound

These cost estimates are somewhat lower than those prepared by Meller.

TABLE 45

ESTIMATED MANUFACTURING COST FOR CONTINUOUS PROCESS USING A THREE-STAGE REACTOR SYSTEM FOR HYDROLYSIS OF WASTE PAPER

Item	Units/Day	Cost	Daily Cost
A. Direct Production Cost			
1. Raw Materials:			
H_2SO_4 (60° Baume - 77.7%)	4.02 Tons	$26.00/Ton	104.60
Limestone (Crushed - 100 Mesh)	3.78 Tons	12.40/Ton	46.90
Wastepaper (Mixed)	80.0 Tons	13.00/Ton	1,040.00
2. Utilities:			
Electricity	15.630 Kwh	0.007/Kwh	109.50
Steam (125% of Process Demand)	285,500 lb	0.52/1000 lb	148.30
Process Water	172,000 Gal.	0.25/1000 Gal.	43.00
3. Operating Labor 3 Men/Shift	72 Man-hrs	3.00/Man-hr	216.00
4. Supervisor 1 Man-Day Shift	8 Man-hrs	3.50/Man-hr	28.00
5. Fringe Benefits - 15% Hourly Wage			36.60
6. Operating Supplies - 10% of Labor			21.60
7. Maintenance and Repairs - 10% F.C.I.			
Labor (Per Year) = 5% F.C.I.			217.00
Overhead & Supplies (Per Year) = 5% F.C.I.			217.00
Direct Production Cost			2,228.50

TABLE 45 (Continued)

B. Fixed Charges	
1. Depreciation - 12 Year Plant Life - Zero Salvage Value = 8-1/3% F.C.I. Per Year	357.00
2. Local Taxes - 2% F.C.I. Per Year	86.70
3. Insurance - 1% F.C.I. Per Year	43.50
Fixed Charges	487.20
C. Plant Overhead - 70% of Operating Labor, Supervision & Maintenance Labor	323.00
D. General Expenses	
1. Administrative Costs - 15% of Operating Labor, Supervision & Maintenance Labor	69.10
2. Distribution and Selling Cost (Not Applicable)	-
3. Research and Development Cost - 5% Product Cost	173.00
4. Financing Interest 4% of Total Capital Investment Per Year	185.00
General Expenses	427.10
Total Production Cost Excluding Income Tax (A + B + C + D)	3,466.00

With on-stream factor = 0.9 the daily sugar production is 62,500 lb

Total Product Cost = $\frac{\$3,466.00}{62,500 \text{ lb}}$ = 5.55¢/lb Sugar

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Note: All plants operated 3 shifts per day, 360 days per year, 190 tons refuse per day.

Source: From Meller, F.H., "Conversion of Organic Solid Wastes into Yeast - An Economic Evaluation," U.S. Environmental Protection Agency, Rockville, Md., 1969.

TABLE 46

DAILY MANUFACTURING COST FOR CONTINUOUS PLANTS OF VARIOUS CAPACITIES USING THREE-STAGE REACTOR FOR HYDROLYSIS OF WASTE PAPER

Item	80 Ton/Day Plant	150 Ton/Day Plant	300 Ton/Day Plant	500 Ton/Day Plant	1000 Ton/Day Plant
A-1 Raw Materials					
H_2SO_4	104.60	196.00	392.00	654.00	1,308.00
Limestone	46.90	88.00	176.00	293.00	586.00
Wastepaper	1,040.00	1,950.00	3,900.00	6,500.00	13,000.00
A-2 Utilities					
Electricity	190.50	357.00	715.00	1,190.00	2,380.00
Steam	148.30	278.00	556.00	927.00	1,854.00
Process Water	43.00	80.60	161.20	269.00	538.00
A-3 Operating Labor	216.00	216.00	216.00	216.00	216.00
A-4 Supervisor	28.00	28.00	28.00	28.00	28.00
A-5 Fringe Benefits	36.60	36.60	36.60	36.60	36.60
A-6 Operating Supplies	21.60	21.60	21.60	21.60	21.60
A-7 Maintenance					
Labor	217.00	337.00	546.00	784.00	1,270.00
Overhead & Supplies	217.00	337.00	546.00	784.00	1,270.00

TABLE 46 (Continued)

B-1 Depreciation	357.00	561.00	910.00	1,305.00	2,110.00
B-2 Local Taxes	86.70	134.80	219.00	314.00	507.00
B-3 Insurance	43.50	67.50	109.30	147.00	254.00
C Plant Overhead	323.00	407.00	553.00	720.00	1,060.00
D-1 Administrative Cost	69.10	87.10	118.50	154.00	227.00
D-2 Distribution & Selling Cost	-	-	-	-	-
D-3 Research & Development	173.00	288.00	509.00	792.00	1,462.00
D-4 Financing Interest	185.00	288.00	470.00	679.00	1,111.00
Daily Production Cost	3,466.00	5,759.00	10,183.00	15,824.00	29,239.00
Production Cost Per Pound	5.55¢ / # Sugar	4.91¢ / # Sugar	4.34¢ / # Sugar	4.05¢ / # Sugar	3.65¢ / # Sugar

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Note: All plants operated 3 shifts per day, 360 days per year. Wastepaper capacities given above are 42% of corresponding refuse capacities.

Source: From Meller, F.H., "Conversion of Organic Solid Wastes into Yeast - An Economic Evaluation," U.S. Environmental Protection Agency, Rockville, Md., 1969.

TABLE 47

PRODUCTION COST OF HYDROLYZATE SUGARS FROM HYDROLYSIS OF REFUSE

Plant Scale	Refuse T/D (30% moisture)	190	357	714	1190	2390
	Dry Waste Paper T/D = 42% of refuse tonnage	80	150	300	500	1000
Gross Production Cost	¢/pound	3.91	3.26	2.68	2.69	2.08
Grinding and Separation	¢/pound	.53	.53	.53	.53	.53
Residue Disposal	¢/pound	.36	.36	.36	.36	.36
Net Production Cost	¢/pound	4.80	4.15	3.57	3.28	2.97

An alternative means of producing a glucose medium for the cultivation of yeast is the application of purified cellulase enzyme systems to wastes. A cellulase is a far more efficient hydrolysis catalyst than acid--one enzyme molecule will do the work of ten acid molecules, if the cellulose polymers are not bonded together in a crystal structure. However, a crystal structure predominates in natural cellulose, and in this case the acid molecules have the advantage that they are small enough to slip between the fibers in the crystalline regions, whereas the enzyme molecules cannot penetrate these regions because of their large size. Enzymatic hydrolysis may be encouraged somewhat by alkali treatment of the substrate to reduce the degree of crystallinity. However, cellulase enzymes are difficult to obtain in large quantity and *in vitro* enzymatic depolymerization is intensely concentration limited--a problem that is not as serious when cellulolytic organisms are cultured because they absorb the hydrolysis products before inhibitation of the enzyme system becomes great.

Small amounts of cellulase are produced for pharmaceutical and research purposes from *Aspergillus niger* and *Trichoderma viride*. Mandels, Weber, and Parizek[46] were able to create by electron bombardment a mutant strain of *Trichoderma viride* (Qm6a) that secretes twice as much cellulase as its parent. Experimental manipulation along this line may be expected in the future to increase the productivity of cellulase producers, but not change the basic chemical efficiency of natural enzyme systems.

Rosenbluth and Wilke[47] present an economic analysis of a hypothetical plant for the enzymatic hydrolysis of waste cellulose. Their design parameters derive from their own experimental observations and the work of Mandels and Weber. Their two-step process involves culturing Trichoderma viride and then applying an enzyme-containing filtrate from this culture to ground cellulosic wastes. Their estimate for a 100-ton-of-cellulose-per-day plant, excluding the cost of separating this cellulose from refuse, indicates a production cost of 5.3¢ per pound of glucose in a 5.3 percent solution. This cost is higher than the estimates of the acid hydrolysis costs of 2¢ to 4¢ per pound of glucose.

The hydrolyzate sugars obtained by acid or enzymatic hydrolysis may be fermented to produce ethanol. The cost of fermentation has been difficult to estimate since no large fermentation plants have been constructed recently to manufacture ethanol. Peppler[48] indicated "production and delivery" costs of 15¢ per gallon of ethanol from molasses; however, Converse, et al., have found that fermentation yield from hydrolyzed refuse is greater than from molasses (85 percent to 94 percent as opposed to 80 percent), perhaps because the impurities present in refuse form an environment particularly conducive to ethanol formation by Saccharomyces cerevisiae. Fagan[49] and Converse, et al., suggest a fermentation cost of about 9¢ per gallon for a plant handling 250 tons of refuse per day with 50 percent paper content and a capital investment of $1.7 million for the fermentation process. They have further considered the cost of cleaning up for discharge the process effluent that has a five-day BOD of 6000 PPM and is produced at a rate of 400,000 gallons per day from a 250-ton-per-day refuse plant. Their estimate is 0.7¢ per gallon of ethanol.

A flow diagram and materials balance for a plant extracting ethanol from acid-hydrolyzed municipal waste is presented in Figure 16 and, similarly, Figure 17 pertains to a plant treating cattle manure.

ii. The Market for Glucose and Ethyl Alcohol

Glucose. The projected demand for dextrose (glucose) and syrup containing dextrose may be estimated as 2317 thousand tons in 1980 and 2904 thousand tons in 1990. This represents only 4.5 percent of the potential amount available from hydrolysis of the cellulose in municipal solid waste in 1980 and only 4.1 percent of the 1990 potential (see Table 48).

FIGURE 16

.FLOW DIAGRAM AND MATERIALS BALANCE FOR THE PRODUCTION OF ETHANOL FROM MUNICIPAL REFUSE

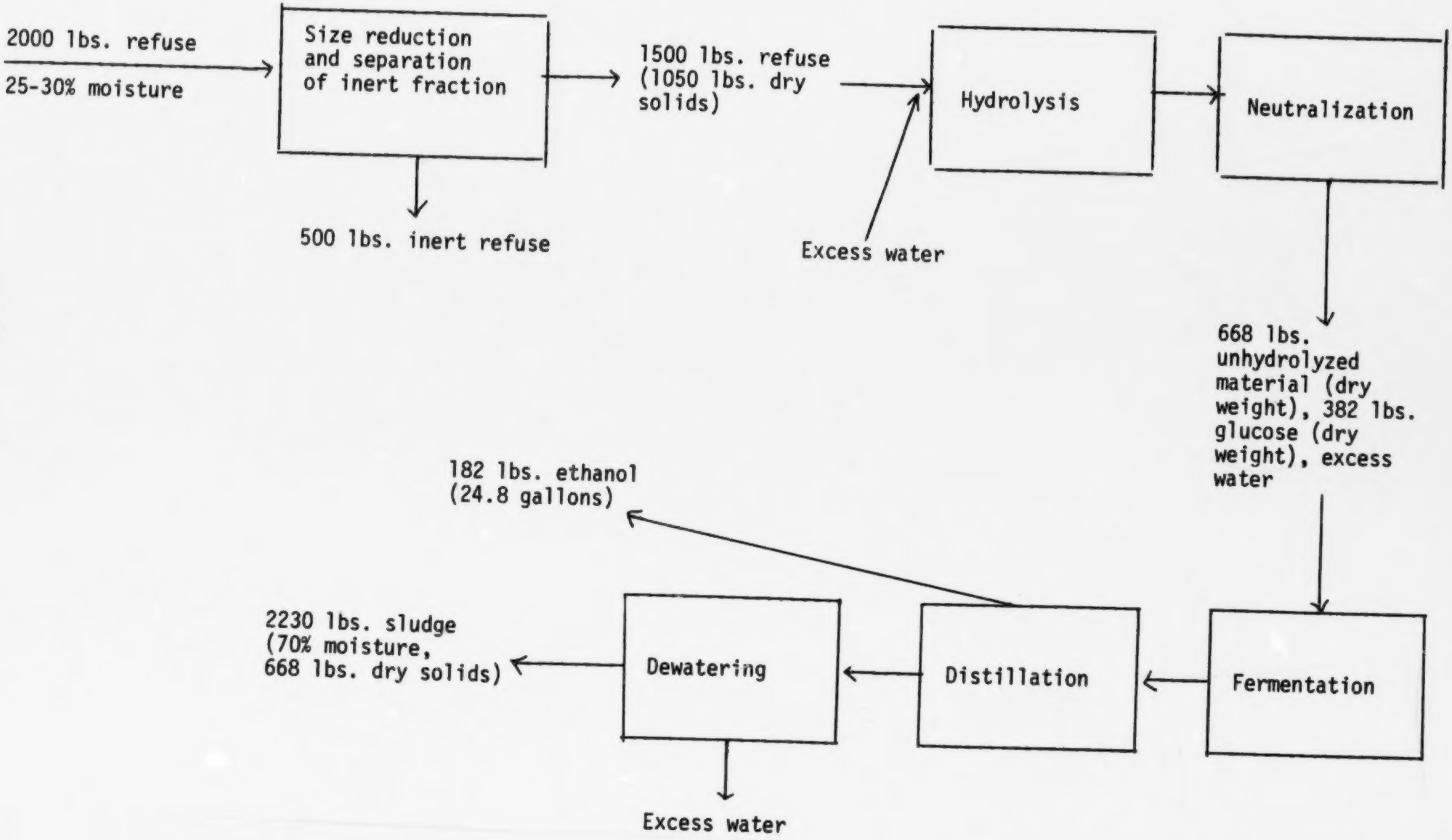

2000 lbs. refuse
25-30% moisture
Size reduction and separation of inert fraction
500 lbs. inert refuse
1500 lbs. refuse (1050 lbs. dry solids)
Excess water
Hydrolysis
Neutralization
668 lbs. unhydrolyzed material (dry weight), 382 lbs. glucose (dry weight), excess water
Fermentation
Distillation
182 lbs. ethanol (24.8 gallons)
Dewatering
Excess water
2230 lbs. sludge (70% moisture, 668 lbs. dry solids)

FIGURE 17

FLOW DIAGRAM AND MATERIALS BALANCE FOR THE PRODUCTION OF ETHANOL FROM CATTLE MANURE

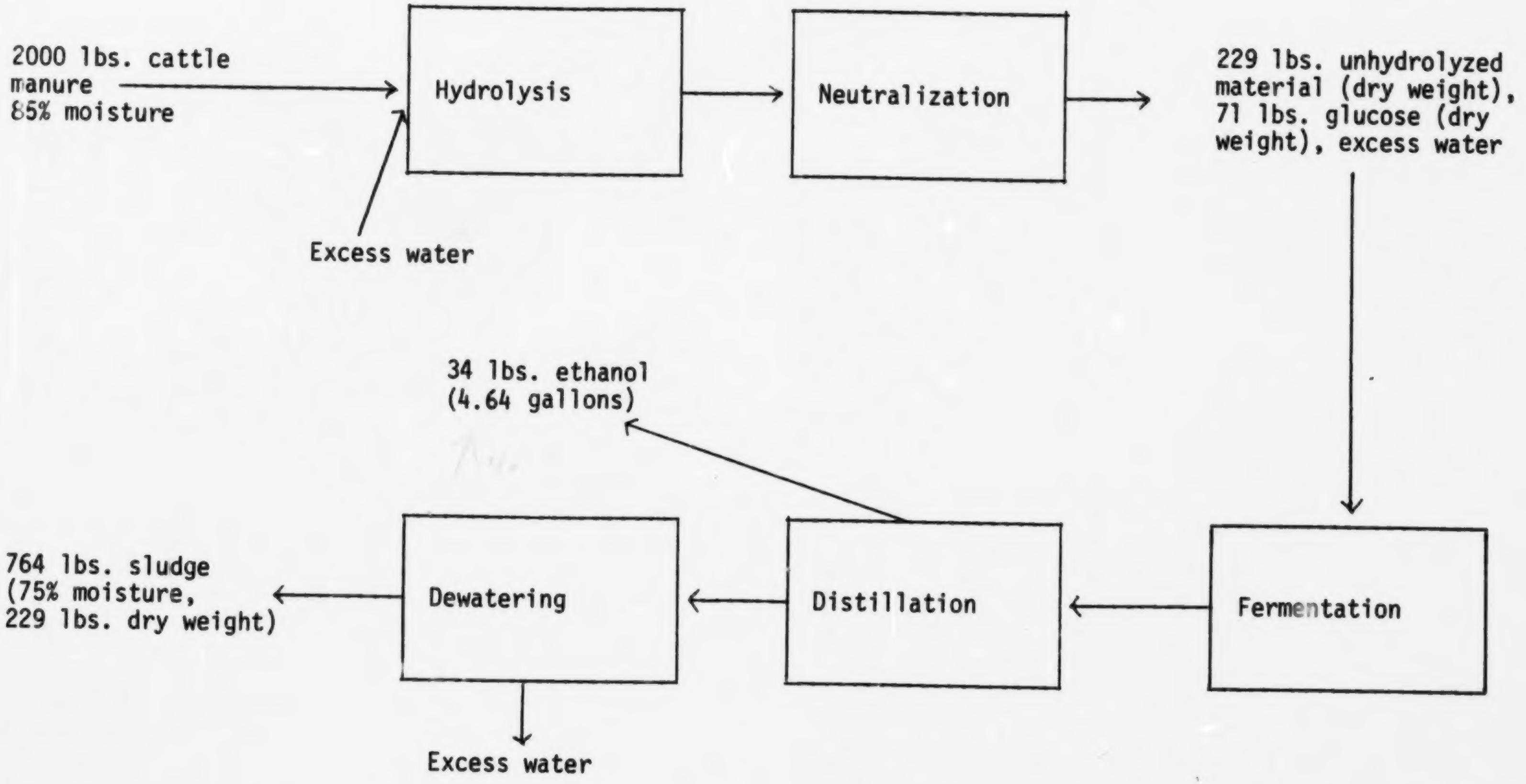


TABLE 48

SUMMARY OF PROJECTED GLUCOSE DEMANDS

	Demands and Potentials 1000 Tons (Dry Basis) 1970	1980	1990
Estimated[a] Dextrose Potential from Solid Municipal Waste	38,200	50,900	71,200
Projected Demand[b]			
1. Dextrose	450.7	545.0	651.0
2. Corn Syrup	1339	1772	2252
3. Total Dextrose and Corn Syrup	1789.7	2317.0	2903.9

[a] Based on acid hydrolysis of refuse from total U.S. population.

[b] Based on data through 1968.

Corn has been and currently is the largest single source of dextrose and syrups. This established source is far from being short in supply. Traditionally only 2.7 to 3.6 percent of domestic corn use has been represented by dextrose and syrup production. Reduction in the harvested acreage of corn over the past two decades as well as increased corn yields per acre further add to the potential excess supply from this established source for the foreseeable future. In addition, valuable byproducts from the wet milling of corn provide revenues which allow dextrose and syrup prices to be adjusted into ranges competitive with other sweeteners.

The present and projected market for dextrose can best be described as inelastic. An apparent saturation of sweets and sweetener usage by the public exists, thus placing an upper limit on the total sweetener consumption. Usage of dextrose and syrup, in turn, is encouraged by placing their prices lower than the price of other sweeteners, but is limited by the physical and chemical characteristics desired in processing and in the finished products. Dextrose and syrup are projected to represent 16.5 percent of the total caloric sweetener consumption in 1980 and 17.9 percent in 1990.

Large quantities of molasses are used in animal feeding, selling for about 2¢ per pound of sugar. However, it cannot be anticipated that a glucose solution from waste cellulose could make significant penetration of the market for feed molasses. Molasses is a byproduct of cane and beet sugar manufacture and as such its price can become negative if sugar manufacturers have trouble disposing of it.

Glucose prices historically have been lower than the price of sugar (sucrose) on a regional basis, presumably to encourage substitution of glucose for sugar wherever possible. As seen in Table 49, the average price of glucose has ranged between 84.9 to 93.6 percent of sugar prices from 1960 to 1968. In 1968, the average percentage was 90.8 and the average price was 9.23¢ per pound of glucose (dry basis).

Corn syrup prices have historically been related to the price of corn, with sugar setting the ceiling on the upward movement. A declining net cost of corn to the producers has resulted in a decreasing price trend in corn syrup as shown in Table 49. The U.S. average corn syrup prices have decreased from 7.72¢ per pound in 1690 to 6.91¢ per pound on a dry basis in 1968.

U.S.-produced corn syrup and glucose are among the lowest priced in the world because of the ample supply of corn available at low net cost and substantial additional income from sale of byproducts such as corn oil and corn gluten feed and meal.

TABLE 49

COMPARATIVE TRENDS IN WHOLESALE DEXTROSE AND CORN SYRUP PRICES

	U. S. Average Dextrose (dry basis, cents per pound)	Percent of Sugar Price	U. S. Average Corn Syrup (dry basis, cents per pound)	Percent of Sugar Price
1960	8.57	93.6	7.72	84.3
1961	8.26	91.7	7.31	84.1
1962	8.27	90.3	7.15	78.1
1963	8.48	84.9	7.40	74.1
1964	8.92	90.1	7.56	76.4
1965	8.63	92.0	7.48	79.7
1966	8.78	91.6	7.25	75.7
1967	9.15	92.0	6.82	68.5
1968	9.23	90.8	6.91	67.9

Source: "Sweetener Consumption, Utilization and Supply Patterns in the United States: Past Trends and Relationships, and Prospects for Target Years 1980 and 2000," unpublished manuscript by F.D. Gray, U.S. Department of Agriculture, Washington, D.C., 1971.

Ethanol. Even with the most optimistic industry projections, the quantity of industrial ethanol potentially derivable by fermentation from solid municipal waste exceeds projected consumption by a factor of 10.6 in 1980 and by a factor of 6.1 in 1990 (see Table 50).

TABLE 50

PRESENT AND PROJECTED INDUSTRIAL ETHANOL CONSUMPTION AND QUANTITIES POTENTIALLY DERIVABLE BY FERMENTATION FROM SOLID MUNICIPAL WASTE
(Millions of Gallons 95% by Volume)

	1970	1980	1990
Potentially derivable from solid municipal waste by fermentation	4,960	6,660	9,250
Consumption:			
Actual	287.9		
Projected optimistically by Industry at 8% cmpd. per annum[a]		620	1,340
Projected optimistically by Industry at 5% cmpd. per annum[a]		467	761
Extrapolated from past consumption pattern[a]		353	555
Projected as a saturated market increasing only with population; complete decay of acetaldehyde usage by 1980[a]		239	280

[a] Projections based on data collected in Chemical Economics Handbook, Stanford Research Institute, Menlo Park, California. Data for past consumption pattern based on total for all others and upper acetaldehyde projections.

Discussion with distributors and producers of ethanol emphasized the specificity of ethanol uses based on its physical and chemical properties. Hence, it is projected that total ethanol usage would not significantly increase if the market price were decreased.

As of January 1972, the industrial ethanol industry was operating at less than 70 percent of capacity and offering discounts in excess of 45 percent on some grades. This has resulted in an average aggregate price of about 44¢ per gallon, with prices as low as 22¢ to 25¢ per gallon for lower priced denatured grades. Simultaneously, production has dropped 29.0 percent from the second half of 1968 to the first half of 1971, indicating a static to decreasing demand for ethanol in spite of price reductions. Projections over the next five years indicate a rise in the average aggregate price to 45¢ to 49¢ per gallon compared to a reported range of 45¢ to 57¢ per gallon for denatured grades as of December 20, 1971.

Dealers and distributors acknowledged the possibility of ethanol replacing a small amount of the methanol, isopropyl solvent market at a competitive price. However, none were definitive on the resulting effect on total ethanol consumption at any price, repeatedly noting that the magnitude of the ethanol market is established by the specificity of ethanol's chemical and physical properties.

iii. Evaluation

Evaluation will be limited here to the extraction of glucose or ethanol from municipal waste. Sufficient experimental work has not been performed on other waste substrates to permit complete evaluation. However, municipal waste is probably the most desirable of the three major waste streams for glucose or ethanol extraction because of its consistently high cellulose content. In addition, only hydrolysis by an acid catalyst will be considered here because enzymatic catalysis appears more expensive, and indeed has not yet even been attempted on a large scale.

Net Cost. Because of the small market for glucose as a constituent of foods, for evaluation purposes a maximum selling price of 2¢ per pound is assumed, comparable to the cost of sugar in molasses used for animal feeding. Thus the net cost of extracting 382pounds of glucose from a ton of refuse is $7.64 to $15.28 (processing cost) plus $1.90 (approximate marketing and distribution cost) less a return of $7.64 = $1.90 to $9.54.

It would cost about 10¢ per gallon of ethanol to ferment hydrolyzed cellulose from waste materials and clean the process effluent. At 90 percent fermentation yield, 16 pounds of sugar are needed to produce a gallon of alcohol. The cost of this much sugar from refuse is estimated as 32¢ to 64¢ from a 400-ton-per-day refuse handling plant. Thus the total cost of ethanol production would be 42¢ to 74¢ per gallon for this plant. The current listed market price of ethanol is 52¢ per gallon, but the market has been weak and the average price recently has been 44¢ per gallon and has gone as low as 22¢ to 25¢ per gallon.

Assuming a recent average price may be obtained, the net cost of extracting 24.8 gallons of ethanol from a ton of refuse would be \$10.40 to \$18.36 (processing cost) plus \$2.73 (approximate marketing and distribution cost) less a return of \$10.90 = \$2.23 to \$10.19

Ratings:
Production of glucose from municipal refuse: 4/8.
Production of ethanol from municipal refuse: 4/8.

Waste Reduction. Production of either glucose or ethanol from municipal refuse results in a sludge of mass comparable to that of the original raw waste which must be disposed of along with the inert refuse that was separated out before processing. Furthermore, the markets for the resources are quite small compared to the quantities potentially available. Thus waste reduction by these schemes would be very small.

Ratings:
Production of glucose from municipal refuse: 1/8.
Production of ethanol from municipal refuse: 1/8.

Flexibility. For the production of either glucose or ethanol from municipal waste: (1) Increase of plastics in the waste stream makes the process less effective; (2) the residue is a sludge, making it difficult to handle; and (3) the product faces competition from other sources that could force prices down. In addition, the fermentation process to produce ethanol is susceptible to any poisons that may appear with unpredictable changes in the waste stream.

Ratings:
Production of glucose from municipal refuse: 2/8
Production of ethanol from municipal refuse: 1/8.

State of Development. (1) State-of-the-art for wood chips, grain, etc. (2) Could be available in less than five years. (3) May have problems gaining FDA or Treasury (ethanol) approval.

Ratings:
Production of glucose from municipal refuse: 4/8.
Production of ethanol from municipal refuse: 4/8.

Conservation of Natural Resources. Glucose: almost none. Ethanol: (1) Almost none if used to replace ethanol derived from petroleum. (2) 3.2×10^9 gallons of ethanol could be produced from the annual wastes from 30 million people. If substituted for gasoline, it would replace 2.3×10^9 gallons per year or 2.2 percent of the annual U.S. gasoline consumption.

Ratings:
Production of glucose from municipal refuse: 2/8.
Production of ethanol from municipal refuse: 4/8.

Weighted Totals:

Production of glucose from municipal refuse:
$4 \times 33 + 1 \times 28 + 2 \times 12 + 4 \times 19 + 2 \times 8 = 276/800.$
Production of ethanol from municipal refuse:
$4 \times 33 + 1 \times 28 + 1 \times 12 + 4 \times 19 + 4 \times 8 = 280/800.$

c. Wet Oxidation

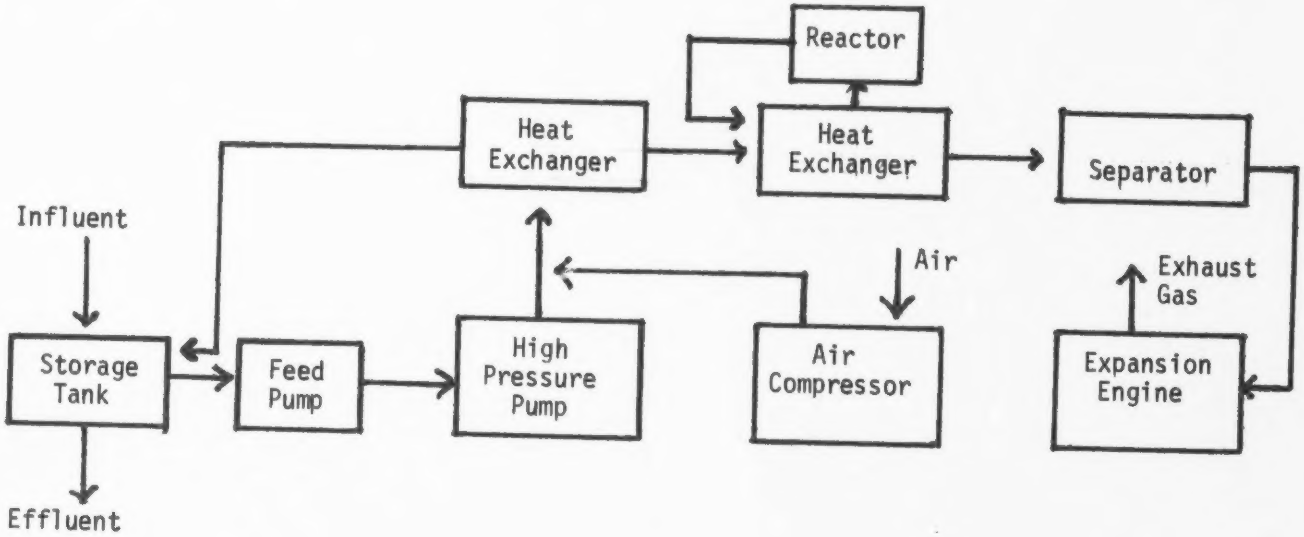
i. Process Description

Wet oxidation[50,51,52] is an incineration technique based on the principle that any aqueously dispersed organic material can be oxidized if sufficient energy is supplied. This process oxidizes sludge solids in an aqueous medium by applying varying degrees of heat and pressure, according to the level of organic-matter destruction desired.

In this process wet sewage sludge is first dewatered and partially dried to 75 percent moisture content. Thickened sludge is then passed through a grinder to reduce particle size. The sludge is pressurized by high-pressure pumps to the necessary operating level and mixed with compressed air. Sludge is then preheated in heat exchangers by heat recovered from reactor products (gases, steam, water). Air is combined with the preheated sludge. When the resultant air-effluent mixture reaches 200 degrees C, the mixture reacts spontaneously and is injected into the bottom of the reactor. Reactor temperature varies between 150 degrees C to the critical temperature of water (372 degrees C), but averages 220-320 degrees C. Pressure ranges from 1000 to 2200 psig. Oxidation occurs as the sludge-air mixture follows a baffled path through the reactor. Reactor effluents pass through heat exchangers, being partially used to preheat the effluent-air mixture about to enter the reactor. A gas-liquid separation is made followed by an ash-liquid separation. The gases (steam, carbon dioxide, and nitrogen) are expanded to provide power for the air compressor and in some instances to generate electrical power. The liquid phase is used to preheat incoming effluent. The separated ash is dewatered in

FIGURE 18

FLOW DIAGRAM FOR THE WET OXIDATION PROCESS



lagoons or by vacuum filters. In this process insoluble organic matter is converted to soluble organic compounds which are then oxidized to form mainly carbon dioxide and water. Organic nitrogen compounds are converted to ammonia and sulfur to sulfates.

The advantages of wet oxidation are: low-temperature operation; flexibility in achieving any degree of oxidation; flexibility in type of sludge handled; production of a small volume of oxidized material that settles rapidly, compacts well, dewaters easily, is susceptible to biologic treatment, and offers few nuisance problems; and operation in a small closed system.

Disadvantages include: odor problems, developed from off-gases and from lagooning of ash containing effluent; air pollution, that could be better controlled by burning at higher temperatures; the need for high-quality supervision and frequent maintenance; the need to return wet oxidation liquors back to wastewater treatment plants with accompanying high organic loads; and high costs associated with construction and operation.

A flow diagram for the wet oxidation of sludge is presented in Figure 18.

Capital costs average about $3,000 per input ton (wet sludge) of daily rated capacity.

Operating costs average $0.70 per input ton (wet sludge).

Total costs average $1.50 per input ton (wet sludge), making wet oxidation almost twice as expensive as conventional multiple hearth incineration.

The capital cost for a 400-ton-per-day plant is estimated to be $1,000,000, which amortizes to $0.70 per ton. Operating costs average between $0.40 and $1.00 per ton, and total costs range from $1.10 to $1.70 per ton.

ii. Evaluation

Net Cost. No resources are recovered, so net cost = total cost = $1.10 to $1.70 per ton.

Rating: 8/8.

Waste Reduction. The residue left by this process is negligible.

Rating: 8/8.

Flexibility. This is similar to incineration of sludges, the only limitation on this process's flexibility being the necessity of locating it at or near a sewage treatment plant.

Rating: 8/8.

State of Development. This is a state-of-the-art technology.

Rating: 8/8.

Conservation of Natural Resources. No resources are recovered.

Rating: 1/8.

Weighted Total:

8x33 + 8x28 + 8x12 + 8x19 + 1x8 = 744/800.

d. Other Chemical Processes

Several other chemical processes for extracting resources from one or more of the major waste streams were examined but not submitted to a full evaluation process because they were either (1) rejected immediately for reasons set forth below, or (2) insufficiently developed to permit realistic evaluation.

i. Chemical Extraction of Oil

The Pittsburgh Energy Research Center of the Bureau of Mines, Department of the Interior,[53] has been conducting laboratory and bench-test scale experiments on extracting a heavy #6 type of oil from organic wastes. The process, the chemistry of which is not yet fully understood, reacts waste, water and carbon monoxide at high pressures (2340 to 5000 psi) and temperatures (450-750 degrees F) sometimes in the presence of a catalyst (e.g., sodium carbonate) for periods of between fifteen minutes to two hours, to produce an oil which is then removed by a solvent extraction process. The nature of the product depends on the temperature and pressure. Yields corresponding to about a quarter ton of oil per ton of municipal waste have been obtained. The work is in a very preliminary stage so that the engineering processes that would be used are unknown at present and hence cost figures are unavailable. It is felt, however, that large-scale (greater than 1000-ton-per-day) processing will be needed. A processing cost figure of $15 per ton of waste is suggested by IR&T on the basis of other high temperature/pressure costs. This is a factor of two or so higher than the pyrolysis process discussed in section 2a which produces a very similar fuel product and is in a more advanced state of development.

ii. Extraction of Chemical Cellulose for the Manufacture of Regenerated Cellulose Products

Cellulose extraction was rejected because (1) manufacturers of regenerated cellulose products demand chemical cellulose of a very high purity (98 percent) which cannot be extracted from municipal waste, and (2) the total U.S. consumption of chemical cellulose from wood pulp in 1970 was only 1.1 million tons with an unspectacular growth rate predicted; this amount could be produced from less than 2 percent of the municipal waste stream.

iii. Sulfur Dioxide Hydrolysis of Sewage Sludge

Some preliminary work has been done on sulfur dioxide hydrolysis of sewage sludge that yields molasses with a 12 percent protein and 24 percent sugar content that can be used as animal feed.[54] However, doubts have been raised as to the technical validity of the work done to date and the cost estimates resulting from it. Better assessment must await further research.

iv. Extraction of Vitamin B-12 from Sewage Sludge

Vitamin B-12 is present in sewage sludge in concentrations of 1 to 2 grams per ton of solids and has been successfully extracted, although not in a quality meeting Food and Drug Administration standards.[55] The market for vitamin B-12 is not great enough for this process to absorb a significant portion of the waste stream. Futhermore, the process effluent is a disposal burden comparable to the original sludge.

3. Biological Processes

a. Composting

i. Process Description

Combustible solid wastes that were at one time parts of living organisms, from cellulose fibers in waste paper to polypeptide chains in leather scraps, can be thought of as raw materials out of their place in a natural ecosystem. The molecular structure of these organic materials is ideally suited to digestion by the organisms that normally feed on them in a natural system, primarily the microorganisms associated with decaying matter. For this reason, composting, which is controlled decay, is found to be efficient in reducing and stabilizing organic wastes and is respected as an ecologically sound practice.

The technique used to manage composting depends upon the particular group of decay organisms being cultivated. Generally, decay may be effected by aerobic or anaerobic, psychrophilic, mesophilic, or thermophilic microorganisms. Anaerobic composting, or putrefaction, is not desirable for waste management because the process is slow and causes the release of noxious odors (except when the digester is designed for the collection of methane gas, as discussed in biological process 3b). Thermophilic digestion is desirable because it is rapid and the temperatures attained, 45 to 60 degrees C, are lethal to the particular microorganisms, worm and fly eggs, and weed seeds that are pests or pathogenic to man or agriculture. Thus, to rapidly reduce organic wastes to a pathogen-free and stable humus-like residue, the proliferation of aerobic thermophiles must be encouraged.

Research done in the 1950's established the conditions necessary for high rate composting. They are a moisture content in wastes from 45 to 60 percent, reduced particle size, presence of the nitrogen and chemical nutrients usually occurring in organic wastes, and agitation in air or the forcing of air through the wastes. Indigenous thermophilic bacterial spores apparently exist in wastes in sufficient number and diversity to make the addition of special inocula superfluous. Although the need and value of such inocula was heatedly debated prior to the 1950's, most composting studies have strongly indicated they are unnecessary.[56,57] Some composting plants in Europe still claim to depend on the use of inocula, and European equipment manufacturers are attempting to interest U.S. customers in such systems. Since the issue is not yet dead, we present Gotaas' argument against the use of inocula as it was published in 1956, shortly after basic studies elucidated the microbiology of composting:

> ...the number of bacteria is rarely a limiting factor in composting because...the indigenous bacteria, which are much better adapted than forms attenuated under laboratory conditions, multiply rapidly, and the rate of composting is governed simply by the environmental conditions.
>
> ...Microbial inoculation would be useful only if the biological population in any emerging environment were unable to develop sufficiently rapidly to take full advantage of the capacity of the environment to support an increase in numbers. In such a case a time-lag would occur which could be overcome by supplementing the initial population indigenous to the refuse. However, no such time-lag has been observed... in composting the usual materials which contain a large indigenous population.[58]

It will be only in the distant future that microbial genetics and ecology might be well enough understood to permit engineering a biological system more efficient than nature's own. The success of the systems that use inocula depends upon providing the proper environment for natural microbial development, as does the success of all composting technologies.

Current composting techniques center either on digestion in exposed piles, or windrows, that are periodically turned or digesting the wastes in an enclosed environment, agitating them mechanically. Although composting may be applied to animal manures, crop residues, and dewatered organic sludges,[59,60,61] its application to the organic fraction of municipal waste will be emphasized in this discussion. As applied to municipal wastes, the composting operation consists of five steps: preparation, digestion, curing, finishing, and storing. The major operations in an advanced composting system are outlined in the flow chart in Figure 19.

Preparation of refuse includes receiving, sorting, magnetic separation, grinding, flotation separation, ballistic separation or air classification, and adding sewage sludge. Receiving equipment acts as a refuse reservoir and provides an even flow of refuse through the plant. Hand sorting as the refuse leaves the receiving area may remove bulky items and salvageable materials such as large pieces of wood and metal, rags, plastics, rubber, leather, glass, and paper. Ferrous metals are removed magnetically. Flotation separation, in a wet handling system, or ballistic or pneumatic separation, in a dry handling system, may be applied after the refuse is pulped or ground in a hammermill. The moisture content of ground refuse will usually have to be raised to 45 to 60 percent from something around 30 percent. If raw or digested sewage sludge is used for this purpose, the compost material benefits by the addition of organic and trace materials, particularly organic nitrogen, while providing for sanitary disposal of the sludge.

Digestion of the refuse occurs in an environment artificially suited to the aerobic thermophiles. In the open windrow method, a long digestion period, four to eight weeks, includes a curing period; whereas in mechanical composting a short digestion period, four to eight days, is followed by a curing period that lasts several days to weeks. The time required for digestion depends on the initial carbon-to-nitrogen (C/N) ratio if proper moisture, particle size, and aerobic conditions are maintained. The higher the C/N ratio, the longer the digestion will take. As the microorganisms digest the refuse, they use the carbon for energy and cell building and the nitrogen for cell building only. The C/N thus becomes smaller in time until the material is stabilized, since the nitrogen remains in the system while the carbon is released as carbon dioxide.

The curing, an aerobic and anaerobic digestion that occurs as the compost is stacked in piles, is necessary for complete

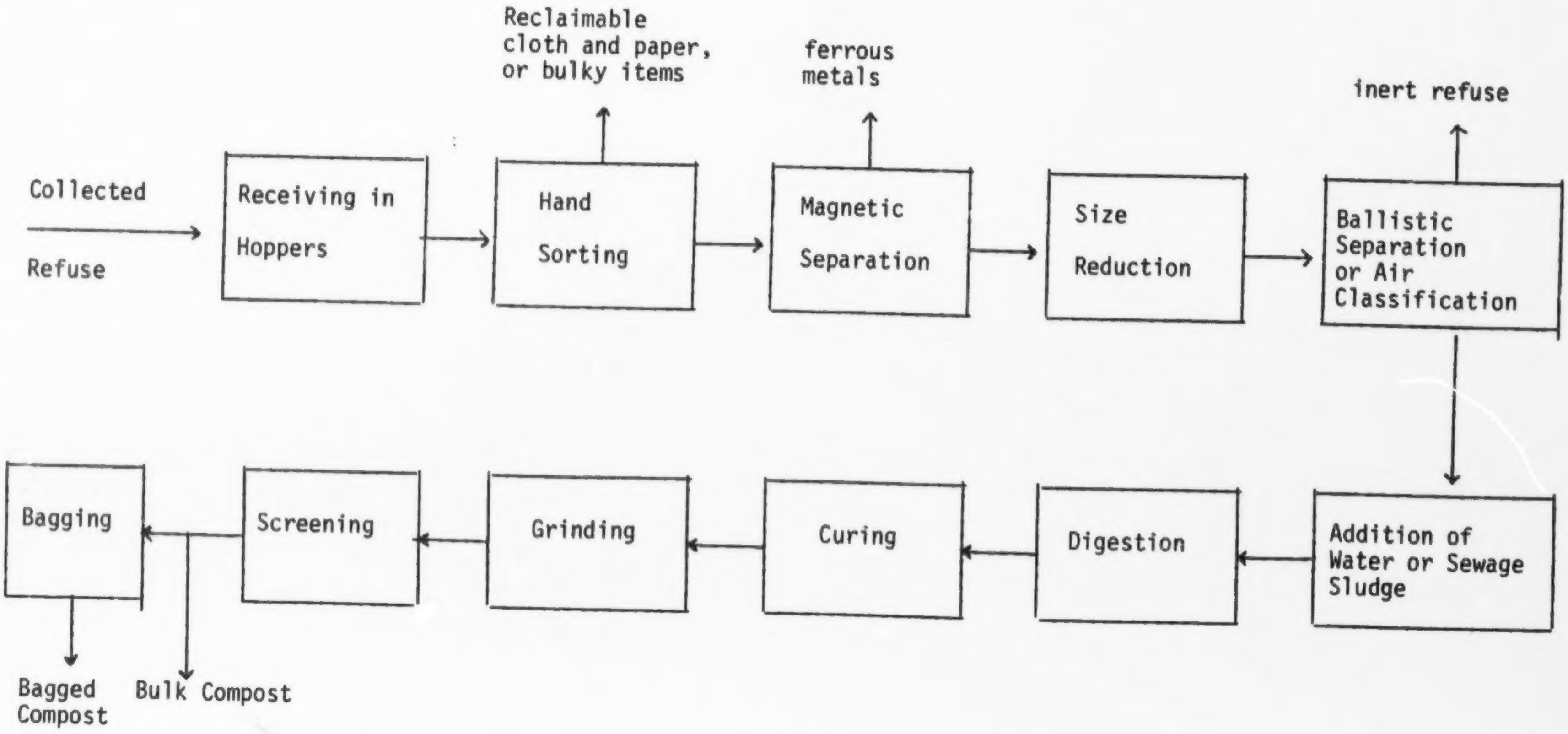


FIGURE 19
FLOW CHART FOR ADVANCED COMPOSTING SYSTEM

stabilization of the compost. Stability is achieved when the compost does not have an unpleasant odor, high temperatures are not maintained, and the carbon-to-nitrogen ratio (C/N) is such that the humus can be applied to the soil. A C/N of 20 is widely accepted as the upper limit for final application to the soil,[62] but the actual availability of the carbon and nitrogen is the determining factor. If much of the carbon is locked up in or by lignin, the C/N ratio can be much higher without leading to a loss of soil nitrogen that would occur if microorganisms could grow using the carbon from the humus and the nitrogen from the soil. The acceptable C/N has to be determined for each compost product and application.

Finishing a compost involves screening and grinding to remove plastics, glass, and materials that might be objectionable in its use. Storage facilities for the compost are necessary since the demand for the humus in agriculture or horticulture will be seasonal. However, the storage period may also serve as the curing phase of the composting process.

A summary[63] of the diverse composting methods recently employed in the management of municipal waste is presented in Table 51. It is evident from this table that composting has contributed successfully to solid waste management in Europe. In 1964, a study was made of fourteen composting plants in Europe and Israel, and it was determined that the average treatment cost was $4.55 per ton of refuse.[64]

However, economic conditions are sufficiently different in Europe that attempts to correlate U.S. and European composting data have been unsuccessful.[65] Therefore, in estimating composting costs we will consider only U.S. composting ventures and data from U.S. composting equipment manufacturers. The methods of predominant interest that have been applied in the United States we will refer to as enclosed system "A" as applied at Altoona, Pennsylvania, and San Juan, Puerto Rico; enclosed system "B" as applied at Norman, Oklahoma (closed 1964), San Fernando, California (closed 1964), and St. Petersburg, Florida (closed 1969); enclosed system "C" as applied at Gainesville, Florida, Houston, Texas, and Largo, Florida (closed 1967); and open windrow composting as applied at Boulder, Colorado, Mobile, Alabama, Wilmington, Ohio (closed 1965), and Johnson City, Tennessee.

In system "A" wet pulping followed by dewatering is employed for size reduction. The reduced refuse is digested in a circular tank and stirred by augers suspended from a rotating bridge. The augurs gradually work the material toward the center of the digester where it is discharged through an opening after five days in the tank.

TABLE 51

TYPICAL COMPOSTING PROCESSES

General Description	Location
Trench in ground, 2' to 3' deep. Material placed in alternate layers of refuse, night soil, earth, straw, etc. No grinding. Turned by hand as often as possible. Detention time of 120-180 days.	Common in India
Ground material is compressed into blocks and stacked for 30-40 days. Aeration by natural diffusion and air flow through stacks. Curing follows initial composting. Blocks are later ground.	Schweinfurt, Germany
Rotating drum, slightly inclined from the horizontal 9' to 12' in diameter, up to 150' long. One to 5 days' digestion followed by windrowing. No grinding. Forced aeration into drum.	Predominantly in Europe
Silo type with 8 decks stacked vertically. Ground refuse is moved downward from deck to deck by ploughs. Air passes upward through the silo. Uses a patented inoculum. Digestion (2-3 days) followed by windrowing.	Heidelberg, Germany; Turgi, Switzerland; Verona and Palermo, Italy; Thessaloniki, Greece
Circular tank. Vertical screws, mounted on two rotating radial arms, keep ground material agitated. Forced aeration through tank bottom and holes in screws. Detention time of 5 days.	Altoona, Pennsylvania, and San Juan, Puerto Rico
Hexagonal drum, three sides of which are screens. Refuse is ground. Batch loaded. Screens are sealed for initial composting. Aeration occurs when drum is rotated with screens open. Detention time of 4 days.	Epsom, England
Ground refuse placed in vertical bin having 4 or 5 perforated decks and special arms to force composting material through perforations. Air is forced through bin. Detention time of 4 to 5 days.	None in operation

TABLE 51 (Continued)

Structure with 6 floors, each equipped to dump ground refuse onto the next lower floor. Aeration effected by dropping from floor to floor. Detention time of 6 days.	Jersey, Channel Islands, Great Britain; and Bangkok, Thailand
Open tanks, 20' wide, 10' deep, 200' to 400' long. Refuse ground. Equipped to give one or two turnins during digestion period (7 days). Air is forced through perforations in bottom of tank.	Houston, Texas, and Gainesville, Florida
Five 9' wide steel conveyor belts arranged to pass material from belt to belt. Each belt is an insulated cell. Air passes upward through digester. Detention time of 5 days.	St. Petersburg, Florida
Four-story bins with clam-shell floors. Ground refuse is dropped from floor to floor. Forced air aeration. Detention time of 20 to 28 days.	None in operation
Two cells consisting of 3 horizontal decks. Horizontal ribbon screws extending the length of each deck recirculate ground refuse from deck to deck. Air is introduced in bottom of cells. Composting followed by curing in a bin.	Kobe, Japan
Towers or silos called "Hygienisators." In sets of 4 towers. Refuse is ground. Forced air aeration. Detention time of 4 days.	Dinard, Plaisir, and Versailles, France; Moscow, U.S.S.R.; Buenos Aires, Argentina
Open windrows, with a "haystack" cross-section. Refuse is ground. Aeration by turning windrows. Detention time depends upon number of turnings and other factors.	Mobile, Alabama; Boulder, Colorado; Johnson City, Tennessee; Europe, Israel; and elsewhere
Unground refuse in open piles, 120 to 180 days. Turned once by grab crane for aeration.	Wijster and Mierlo, the Netherlands

System "B" involves size reduction by grinding and the refuse is digested on five stacked conveyors. On the average of once a day the material is dumped or transferred to a lower conveyor. A fan supplies air to the compost.

System "C" involves grinding of the refuse and digestion in long, trench-like tanks into which air is forced through perforations and in which the refuse is turned once or twice during a seven-day digestion period.

At Johnson City, Tennessee, in a typical open windrow system, refuse is ground and mixed with sewage sludge before piling in windrows. The windrows are turned once a week during the six-week digestion period.

We have made approximate cost estimates for all these processes and these appear in Tables 52 through 55. The capital costs, power specifications and labor requirements for the enclosed systems were compiled from the literature or through communication with the manufacturers and the municipalities or corporations which have used these systems. We have calculated the cost of capital amortization for these systems on a per-ton-of-refuse-processed basis by assuming a 20-year lifetime for the plant and 10 percent interest charges on the investment. All the mechanical systems are assumed to be operated on a single-shift basis, 8 hours per day, 260 days per year. Utility costs were determined from the equipment power specifications assuming a load factor of 0.6, and assuming that all the power is obtained from electricity at a cost of 1.5¢ per Kwh and that total utility costs (including power, space heat, water, and sewer facilities) are twice the power cost. Labor and administration costs (including labor, supervision, fringe benefits, plant and payroll overhead, maintenance and repair, and insurance) were estimated as 250 percent of the labor cost alone. Since the total labor and administration cost thus depends on basic wages, and these may vary considerably, this cost is given as a range that encompasses a $2-per-hour to $4-per-hour basic wage for plant labor. Wherever possible, the total estimated cost per ton to process the refuse is compared in the table with the equipment manufacturer's estimate or the real cost experience, but these latter numbers are not comparable from system to system since they rely on different assumptions or conditions. The capital and operating costs for windrow composting are those estimated from the experience at Johnson City; capital amortization we estimated as with the other systems, except for the two-shift operations, where a ten-year life was taken to provide an upper limit for amortization cost range. The Johnson City plant included equipment for dewatering sludge, so the cost of such equipment is included in the capital cost projections. None of the estimates made here include the cost of land or the taxes thereon.

TABLE 52

COST OF COMPOSTING WITH SYSTEM "A"

SCALE		CAPITAL[10]	AMORTIZATION		UTILITY		LABOR AND ADMINISTRATION		TOTAL	COST EXPERIENCE
			20-year life; 10% interest							
Tons per day (one shift)	Tons per yr. (260 days per year operation)		Yearly	$ per ton of refuse	10/ Horsepower	$ Per ton of refuse	10/ Men	$ Per ton of refuse	$ Per ton of refuse	Equipment manufacturers estimate -- $ per ton of of refuse
100	26,000	1,370,000	160,000	6.15	930	1.00	11	4.40-8.80	11.55-15.95	(12.95)
200	52,000	2,000,000	234,000	4.50	1,590	0.86	18	3.60-7.20	8.96-12.57	(10.20)
300	78,000	2,510,000	293,000	3.75	1,830	0.66	25	3.34-6.68	7.75-11.09	(8.88)
400	104,000	3,210,000	375,000	3.60	2,560	0.69	30	3.00-6.00	7.29- 10.29	(8.50)

NOTE: Capital Cost Estimate Based on 1967 Reference.

TABLE 53

COST OF COMPOSTING WITH SYSTEM "B"

SCALE		CAPITAL[10]	AMORTIZATION		UTILITY		LABOR AND ADMINISTRATION		TOTAL	COST EXPERIENCE
			20-year life; 10% interest							
Tons per day (one shift)	Tons per yr. (260 days per year operation)		Yearly	$ per ton of refuse	10/ Horsepower	$ Per ton of refuse	10/ Men	$ Per ton of refuse	$ Per ton of refuse	Equipment manufacturers estimate -- $ per ton of of refuse
100	26,000	1,400,000	164,000	6.30	600	0.65	20	8.00-16.00	14.95-22.95	
105 data from St. Petersburg plant)	27,300	1,500,000	176,000	6.45	--	--	--	--	--	
200	52,000	2,100,000	246,000	4.73	800	0.43	28	5.60-11.20	10.76-16.36	
300	78,000	2,700,000	316,000	4.05	950	0.34	36	4.80- 9.60	9.19-13.99	
400	104,000	3,200,000	374,000	3.59	1100	0.30	45	4.50- 9.00	8.39-12.89	

NOTE: Estimates based on 1967 reference.

TABLE 54

COST OF COMPOSTING WITH SYSTEM "C"

SCALE		CAPITAL[10]	AMORTIZATION		UTILITY		LABOR AND ADMINISTRATION		TOTAL	COST EXPERIENCE
			20-year life; 10% interest							
Tons per day (one shift)	Tons per yr. (260 days per year operation)		Yearly	$ per ton of refuse	10/ Horsepower	$ Per ton of refuse	10/ Men	$ Per ton of refuse	$ Per ton of refuse	Equipment manufacturers estimate -- $ per ton of of refuse
100	26,000	900,000	105,000	4.04	1,250	1.34	12	4.82-9.64	10.20-15.02	
150 data from Gainesville plant	39,000	1,250,000	146,000	3.75	1,100	0.79	--	--	--	(10.53) Includes disposal of non-compostables
200	52,000	1,200,000	140,000	2.70	1,700	0.92	17	3.40-6.80	7.02-10.42	
300	78,000	1,500,000	175,000	2.24	1,900	0.68	25	3.34-6.68	6.26- 9.60	
360 data from Houston plant	93,000	1,750,000	204,000	2.20	--	--	--	--	--	
400	104,000	1,600,000	187,000	1.80	2,000	0.54	30	3.00-6.00	5.34- 8.34	

NOTE: Estimates based on 1967 reference.

TABLE 55

COST OF COMPOSTING WITH OPEN WINDROWS

SCALE			CAPITAL 11/	AMORTIZATION				OPERATING AND MAINTENANCE	TOTAL
tons per day	tons per year	shifts		20 year life; 10% interest		10 year life; 10% interest		$ per ton of refuse	$ per ton of refuse
				YEARLY	$ PER TON OF REFUSE	YEARLY	$ PER TON OF REFUSE		
50	13,000	1	819,500	95,900	7.33			13.65	21.03
100	26,000	2	840,500	98,400	3.78	134,800	5.18	10.50	14.28-15.68
100	26,000	1	989,100	115,800	4.46			9.90	14.36
200	52,000	2	1,071,100	125,500	2.42	172,000	3.30	8.70	11.12-12.00

Open windrow composting may appear advantageous because of the low capital cost. However, the digestion period in windrow composting is long (about six weeks) and the land requirements great (ten acres for a small 50-ton-per-day plant). Furthermore, it is difficult to maintain the proper moisture in the exposed windrow. Wet weather may soak the windrows and lead to anaerobic digestion, causing offensive odors to be produced. These disadvantages will probably prevent windrow composting from being applied to nonrural waste problems.

A stable compost product can be obtained from any of the processes discussed and the characteristics of the compost should be similar in any case, providing that the same waste source is used and the same amount of finishing is applied. The chemical composition of the compost produced in the Johnson City plant is presented in Table 56,[66] and the values for N (0.85%-1.07%), K (0.25%-0.40%), P (0.20%-0.34%), and Ca (0.75%-3.11%) correspond to those found by investigators of other composts.[67] However, proper management of composting requires that continuous attention be paid to the operating parameters such as moisture content, particle size, and retention time in the digester as these will have to be adjusted differently for different wastes and seasons. Some of the high costs of more expensive systems may reflect good management and control. On the other hand, more economical operations may not provide sufficient control over conditions to prevent anaerobic digestion and the production of odors.

Composting sewage sludge independent of refuse is a similar process to composting municipal refuse except that the preparation of the waste is different. For sewage sludge, instead of separation, size reduction and the addition of moisture, the sludge must be dewatered to less than 60 percent moisture content in order for mechanical agitation to be practical in aerating the sludge. In addition, the digester is more complicated because the sludge, even at 60 percent moisture, is more difficult to agitate and aerate than the light fraction of municipal refuse. Similar problems arise in the composting of manure, although manures may be collected at a lower moisture content than sludge, and if they contain a high fiber content, will be easier to aerate than sludge.

A materials balance for the application of the composting process to the three major waste streams is presented in Table 57.

In evaluating the research and development needs of composting technology, it seems unlikely that the state of the art of composting will be the factor that limits its use in solid waste management.[68] The basic fundamentals of composting and the principles that engineered systems must be designed to exploit are well established. Debugging in actual operating experience will complete future development tasks.

TABLE 56

ELEMENTS IN 42-DAY-OLD COMPOST AT JOHNSON CITY, TENNESSEE

Element	Percent dry weight (average) Containing Sludge	Percent dry weight (average) Without Sludge	Range (All Samples)
Carbon	33.07	32.89	26.23 - 37.53
Nitrogen	0.94	0.91	0.85 - 1.07
Potassium	0.28	0.33	0.25 - 0.40
Sodium	0.42	0.41	0.36 - 0.51
Calcium	1.41	1.91	0.75 - 3.11
Phosphorus	0.28	0.22	0.20 - 0.34
Magnesium	1.56	1.92	0.83 - 2.52
Iron	1.07	1.10	0.55 - 1.68
Aluminum	1.19	1.15	0.32 - 2.67
Copper	<0.05	<0.03	
Manganese	<0.05	<0.05	
Nickel	<0.01	<0.01	
Zinc	<0.005	<0.005	
Boron	<0.0005	<0.0005	
Mercury	not detected	not detected	
Lead	not detected	not detected	

TABLE 57

MATERIALS BALANCE FOR AEROBIC COMPOSTING

Input	Output
1 ton municipal refuse (30% moisture)	1. 0.25 ton inert materials
	2. 0.50 ton compost (30% moisture)
1 ton sewage sludge (96% moisture)	1. 0.04 ton compost (30% moisture)
	2. excess water
1 ton animal manure (85% moisture)	1. 0.15 ton compost (30% moisture)
	2. excess water

ii. The Market for Composted Municipal Waste, Sewage Sludge, or Manure

Previously, large-scale attempts to market compost made from municipal waste, as an agricultural soil conditioner, have not been successful in the United States. This is because chemical fertilizers and advanced plowing-cultivating techniques in most cases can provide equal or superior benefits at lower costs than the application of compost. The limited size of the current total U.S. market for major types of organic soil conditioners is evident from Table 58.

For general landscaping applications, the only potential market for compost is as an ingredient of "top dressings" for golf course turfs and park lawns. As indicated in Table 59, this market could at most reach 400,000 tons annually by 1990.

The trend toward containerized growing by nurseries and the needs of home gardeners will provide a steady expansion of luxury demand for artificial growing media, soil conditioners and mulches. By 1990, the total potential market for compost as an ingredient of such products will reach 440,000 tons per year, as indicated in Table 60.

More important is the potential for compost as an organic carrier for non-farm fertilizers. As indicated in Table 61, this use could exceed 3,000,000 tons per year by 1990. The compost used will have a value of $6 to $8 per ton delivered to the plant.

Independent of shredding, the composting process itself reduces the volume of municipal refuse by one-half. This means that composting can double the life of a sanitary landfill and, consequently, half the related costs of land acquisition.

Compost, itself, can be highly resistant to compaction. It can support loads up to two and one-half times as great as those borne by some weak soils. Hence, if compost is used in lieu of refuse as a fill material, the landfill site can be sold for immediate commercial use directly upon its closing.

A related use is reclamation of depleted strip mines. Superficially, transportation costs from urban areas to mines appear prohibitive. However, placing compost plants adjacent to major coal users could take advantage of the normally empty back-haul to the mines.

It appears feasible to feed cattle diets containing up to 10 percent compost without deleterious effects on weight gain or meat quality. Should compost be used as a roughage in feedlot diets, Table 62 indicates that up to 2,700,000 tons could be sold per year in the 1980's at prices of $4 to $6 per ton, f.o.b., dealer dock.

TABLE 58

CONSUMPTION OF SPECIFIC TYPES OF NATURAL ORGANIC FERTILIZERS IN THE UNITED STATES: 1965-70

	Type of Fertilizer 10^3 tons/yr				
Year	Dried Manure	Activated Sewage Sludge	Other Sewage Sludge	Compost	All Others
1965	360	88	43	54	44
1966	357	92	41	36	36
1967	366	92	33	35	28
1968	363	87	51	41	29
1969	351	77	54	13	35
1970	342	65	53	7	34

Source: Consumption of Commercial Fertilizers in the United States. Years ended June 30, 1966-70, USDA, Statistical Reporting Services. Crop Reporting Board, Sp. Dr. 7, Washington, D.C.

TABLE 59

POTENTIAL MARKET FOR TOP DRESSINGS

Year	Total Tons Used[a]	Potential Use of Compost as a Substitute Material
1970	300,000	---
1980	490,000	120,000[b]
1990	800,000	400,000[c]

[a] Assuming a compounded growth rate of 5 percent per year.
[b] Assuming maximum likely market penetration of 25 percent.
[c] Assuming maximum likely market penetration of 50 percent.

TABLE 60

POTENTIAL MARKET FOR COMPOST USE IN LUXURY GARDENING

Year	Total Tons of Humus-Like Material, Mulches, & Soil Conditioners Used	Potential Use of Compost as a Substitute Material
1970	340,000	---
1980	550,000	140,000[a]
1990	890,000	440,000[b]

[a] Assuming maximum likely market penetration of 25 percent.
[b] Assuming maximum likely market penetration of 50 percent.

TABLE 61

POTENTIAL MARKET FOR COMPOST USED AS A CARRIER OF NON-FARM FERTILIZERS

Year	Tons of Fertilizer Used	Tons of Carrier Used[a]	Potential Use of Compost as a Carrier Material
1960	2,650,000	1,320,000	--
1965	3,550,000	1,780,000	--
1970	4,760,000	2,380,000	--
1980	7,780,000	3,890,000	970,000[b]
1990	12,700,000	6,350,000	3,170,000[c]

[a] Assuming 50 percent of fertilizer is carried.
[b] Assuming maximum likely market penetration of 25 percent.
[c] Assuming maximum likely market penetration of 50 percent.

TABLE 62

PROJECTED MARKET FOR COMPOST AS A HAY SUBSTITUTE: 1982-1985

Price Per Ton	Estimated Market Penetration	Estimated Tons Sold[a]
$17.00	10%	280
16.00	20	560
15.00	30	840
14.00	40	1,120
13.00	50	1,140
12.00	60	1,680
10.00	70	1,960
8.00	80	2,240
6.00	90	2,520
4.00	100	2,800

[a] In thousands.

Uniform quality, biologically stable compost provides an excellent raw material for insulating and hard boards. Plastic residues in the original refuse provide most of the necessary binder. The potential market for such compost-based building materials can exceed 1,500,000 tons by 1990.

Table 63 presents a comparison of the potential future supply of compost and the sum of the potential markets listed above that might be profitably entered without major subsidy. These markets include landscaping applications, nurseries, non-farm fertilizers, cattle feed, and building materials, as mentioned above. Since this total market is small, and schemes for more widespread use of compost are highly speculative at the present, we have used a low market figure for evaluation purposes.

TABLE 63

POTENTIAL SUPPLY AND MARKET FOR COMPOST DERIVED FROM MUNICIPAL REFUSE, ANIMAL MANURE, AND SEWAGE SLUDGE
(In 10^3 Tons)

Year	Supply	Market
1970	360,000	7
1980	515,000	4,630
1990	643,000	8,510

iii. Evaluation

Net Cost. The cost of operating a large, 400-ton-per-day municipal refuse composting plant with enclosed, mechanical digestion is estimated above to be from $5.47 to $13.52 per ton of refuse, not including the cost of land purchase or taxes.

Raising the moisture content of refuse by adding sewage sludge provides a credit to the cost of the composting operation. However, a composting plant cannot accept all of the wet, raw sludge produced by the community it serves since it would take, on the average, the refuse from 2.54 people to accept the sludge from one person. (One person yields 0.35 pounds of undigested sewage solids in a day, or 8.74 pounds of sludge at 4 percent solids. To raise the moisture content of 1500 pounds of compostable material from 30 percent to 60 percent requires 1250 pounds of wet sludge. 1250 pounds of sludge is generated by 143 people and 1500 pounds of compostable material by 364 people; 364/143 = 2.54.) Some dewatering of sludge must be performed, but at less than 91 percent moisture all of the sludge from the community could be accepted by the composting plant. Sludge dewatered to 70 percent to 80 percent moisture normally costs a community about $2 per ton to dispose of by landfill, or as much as $5 per ton if incineration is the only alternative.[69] Thus for sludge disposal alone, ignoring the savings in dewatering costs, the composting plant may be paid $0.51 to $1.28 per ton of refuse they process. (Each ton of refuse is mixed with 128 pounds of sewage solids that would otherwise appear in 0.256 tons of sludge at 75 percent moisture.)

Another fraction of the composting cost can be recovered by salvage of noncompostable materials, if markets for these materials exist. Salvageable ferrous metal and cans may comprise 10 percent of the incoming refuse and have a value of $10 per ton ($1 per ton of refuse); glass, 10 percent of the refuse with a value of $10 per ton ($1 per ton of refuse); and salvageable paper, 15 percent of the refuse with a value of $12 per ton ($1.80 per ton of refuse). A favorable realization of salvaging strategies might then return a total of $3.80 per ton of refuse.

The cost of landfilling noncompostable and non-salvageable material must be added to the process costs. It should be anticipated that some items which can be neither composted nor salvaged will always appear in the refuse, and so a landfill site must be available to the compost plant. If the landfilling charge is $2.50 per ton, the liability is $0.13 to $0.63 per ton of refuse for burial of 5 percent to 25 percent of the incoming refuse.

The composting process reduces the volume and dry weight of compostable materials by 30 percent and about 75 percent of municipal refuse is compostable. Thus one ton of compost is produced from two tons of refuse. Optimistically this would cost $0.39 per ton of refuse if the least expensive plant is operated, salvage is maximized, and sludge is accepted that would normally have to be incinerated. Less optimistically, it would cost $5.97 per ton of refuse in the least expensive plant if salvage were unsuccessful and sludge were not accepted. Pessimistically, the cost could be $13.52 per ton of refuse for the most expensive plant without salvage or sludge credits. Thus the price of compost sold, if all were sold, in order for the plant to break even would have to be $0.78, $11.94, or $27.04 per ton for the three cases mentioned above. For each dollar per ton of dumping fee charged the city, the price of the compost could be lowered $2 per ton. If the compost cannot be sold or given away, and the compost is landfilled at a cost of $2.50 per ton, the total cost for waste disposal in the three cases above would be $1.64 per ton, $7.22 per ton, and $14.77 per ton of waste. Because of the anticipated difficulty of marketing compost on a large scale, net cost was graded assuming that the disposal of the compost is indeed a cost liability.

The cost of composting sewage sludge was derived from municipal waste costs, taking into consideration the different preparation required of the waste and differences in the digestion apparatus. Negligible credit has been taken for sale of the compost as distribution costs are comparable to the expected price of the product, and, again, the market is exceedingly small.

The cost of composting animal manure was similarly derived from the cost of composting municipal refuse.

Ratings:
Composting municipal refuse: 4/8.
Composting sewage sludge--$1.10 to $1.60 per ton of sludge (96 percent moisture): 8/8.
Composting animal manure--$3.10 to $6.40 per ton of manure (85 percent moisture): 2/8.

Waste Reduction. Because of the small market for compost, the composting process can be applied only to a very small fraction of the total of each waste stream.

Ratings: Composting municipal refuse: 1/8.
Composting sewage sludge: 1/8.
Composting animal manure: 1/8.

Flexibility. The composting process becomes less efficient if the plastics content of municipal refuse increases, and is susceptible to uncontrolled components of the waste stream that might discourage bacterial activity. Municipal waste is generated distant from the agricultural compost market.

Sewage sludge is generated distant from the agricultural market for compost. Process may be susceptible to toxins in the sludge.

Animal manure is generated near the agricultural market for compost, and it is possible to assure that nothing is included in the manure that would discourage the composting process.

Ratings: Composting municipal refuse: 4/8.
Composting sewage sludge: 4/8.
Composting animal manure: 8/8.

State of Development. Composting municipal refuse and animal manure are state-of-the-art technologies for which equipment is immediately available.

Sewage sludge has not been composted on a large scale, but should present no major problems. A system could be available in less than five years.

Ratings: Composting municipal waste: 8/8.
Composting animal manure: 8/8.
Composting sewage sludge: 4/8.

Conservation of Natural Resources For the small market predicted, the saving of natural resources is negligible. Should a national soil conservation program get under way using compost in large amounts, the results could obviously be very different, but impossible for us to quantify here.

Ratings: Composting municipal refuse: 2/8.
Composting sewage sludge: 2/8.
Composting animal manure: 2/8.

Weighted Totals:

Composting municipal refuse:
4x33 + 1x28 + 4x12 + 8x19 + 2x8 = 376/800.
Composting sewage sludge:
8x33 + 1x28 + 4x12 + 4x19 + 2x8 = 432/800.
Composting animal manure:
2x33 + 1x28 + 8x12 + 8x19 + 2x8 = 358/800.

b. Production of Methane by Anaerobic Digestion

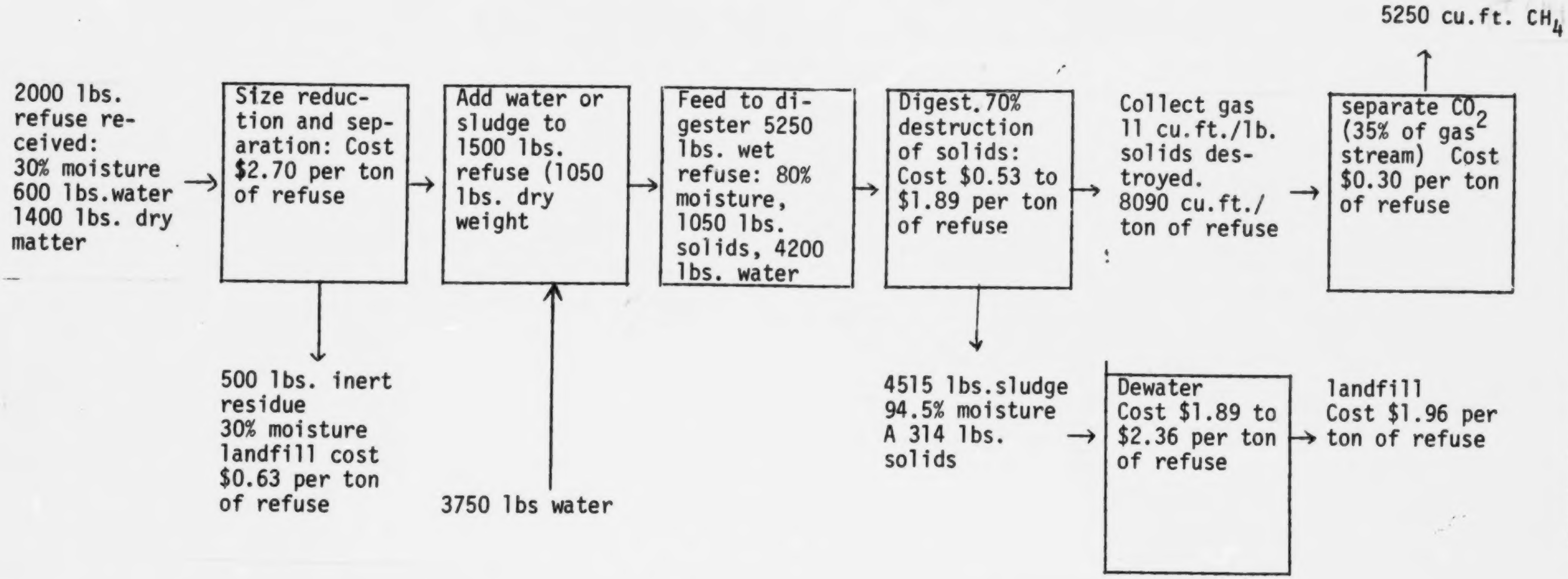
i. Process Description

One way of conserving and utilizing the chemical energy in combustible wastes is to allow anaerobic organisms to digest them and release methane gas.[70] The digestion process converts complex waste to a residue enriched in the original nutrients, and not particularly susceptible to further decay, which can be used as landfill or soil conditioner.

The anaerobic and facultative anaerobic organisms involved in such a process are similar to those occurring in conventional sewage sludge digestion. Experimental work[71,72] has indicated the capability of these organisms to degrade complex municipal paper waste and garbage. The waste substrates are initially attacked by microorganisms that produce organic acids from carbohydrates and amino

FIGURE 20

METHANE PRODUCTION FROM MUNICIPAL REFUSE
(digestion costs estimate based on sewage digestion costs in 1968)


2000 lbs. refuse received: 30% moisture 600 lbs.water 1400 lbs. dry matter
Size reduction and separation: Cost $2.70 per ton of refuse
500 lbs. inert residue 30% moisture landfill cost $0.63 per ton of refuse
Add water or sludge to 1500 lbs. refuse (1050 lbs. dry weight
3750 lbs water
Feed to digester 5250 lbs. wet refuse: 80% moisture, 1050 lbs. solids, 4200 lbs. water
Digest. 70% destruction of solids: Cost $0.53 to $1.89 per ton of refuse
4515 lbs.sludge 94.5% moisture A 314 lbs. solids
Collect gas 11 cu.ft./lb. solids destroyed. 8090 cu.ft./ ton of refuse
separate CO2 (35% of gas stream) Cost $0.30 per ton of refuse
5250 cu.ft. CH4
Dewater Cost $1.89 to $2.36 per ton of refuse
landfill Cost $1.96 per ton of refuse

acids. Methanogenic bacteria then digest the acids and produce methane. The methane producers are sensitive to low pH, but in sewage sludge digestion the organic acids do not cause the pH to drop too low because of the buffering provided by ammonia from deamination of the amino acids. However, municipal refuse has such a low protein content that artificial pH control is found necessary for proper digestion to occur. Whereas in the aerobic digestion of carbohydrates 484-674 K cal per mole of hexose digested is released and partially utilized in cell building, in anaerobic digestion only 26 K cal per mole of hexose digested is released, the rest of the energy appearing in methane.

Experimental data enable us to visualize a full-scale anaerobic digestion plant that processes municipal refuse. The complete process involves grinding the refuse, separation of inert material, addition of sewage sludge or water, digestion, dewatering and disposal of residue, and scrubbing carbon dioxide from the digester gas. The mass balances and costs for these steps are summarized in the flow diagram in Figure 20.

Grinding of the refuse is necessary to facilitate separation of inert materials and rapid microbial digestion. Grinding and pneumatic separation of paper we have estimated in section 4b to cost $2.70 per ton of refuse. Alternative size reduction and separation may be performed in a wet handling system such as described in section 4a on wet fiber recovery. The costs of such a system range from $7.50 per ton of refuse for a 175-ton-per-day plant to $2.80 per ton of refuse for a 1000-ton-per-day plant. About 25 percent of the incoming refuse will be biologically inert and separated out. If salvage is not practical, this refuse must be landfilled for a representative cost of $2.50 per ton landfilled.

The moisture content of the refuse is raised to at least 80 percent to prepare it for digestion by the addition of water or 4 percent sludge from the local sewage treatment plant. The plant can be designed so that all of the sludge concentrated from sewage can be accepted. Digestion of the refuse slurry will require continuous stirring. Deposition of sediment in the digester and significant wear of the stirring mechanism occurred in experimental trials and present unique problems that will require inventive engineering solutions in a full-scale plant. The digestion temperature will have to be artificially maintained at 35 degrees C since the mesophilic biodegradation is not highly exothermic. Some of the methane produced can be used for this purpose. Retention time will be on the order of 30 days, necessitating a digester volume of 2400 cubic feet per daily ton of refuse. Conventional sewage sludge digestion does not face the engineering problems of handling a high-solids, abrasive slurry, or extensive chemical buffering, and we thus anticipate that the costs of sewage sludge digestion be taken as a minimum estimate of the cost of digestion of a refuse slurry. A review of these costs indicates a cost range of $5 to $18 per ton of dry solids.[73] Translating these costs on the basis of digester volume (noting that the refuse slurry requires a smaller volume per ton of dry solids because its moisture content is 80 percent instead of the 95 percent for sewage sludge), digestion of the refuse would cost $1 to $3.60 per ton dry solids in the digester, or $0.53 to $1.89 per ton of refuse received at the plant. If a slurry of only 80 percent water is to thick to be conveniently handled, increasing the moisture content significantly increases the volume requirements. Raising the moisture content to 90 percent would necessitate doubling the volume of the digester, and increasing costs accordingly.

Experimental data indicate a 65 to 70 percent destruction of volatile solids occurs after retention in the digester for 30 days at 35 degrees C. Eleven s.c.f. of digester gas containing 65 percent methane by volume are produced per pound of volatile solids destroyed. If all of the solids introduced to the digester were volatile, then 8090 s.c.f. of gas would be produced from a ton of refuse. The effluent from the digester will be only 5.5 percent solids and thus presents a difficult disposal problem, one similar in nature and comparable in size to the disposal of wet sludge from a sewage treatment plant serving the same population of refuse generators. The effluent must be dewatered and then landfilled, dumped at sea, incinerated or spread on land as a soil conditioner. Dewatering sewage sludges by filtration or centrifugation to 75 percent moisture costs, on the average, $12 to $15 per ton of solids[74] which is $1.89 to $2.36 per ton of refuse. The sludge may then be landfilled along with the inert fraction of the refuse at a cost of $2.50 per ton of sludge or $1.96 per ton of refuse. Marketing the sludge as a soil conditioner would require inclusion of a costly, high-temperature drying step, which will not be considered here.

For the digester gas to be marketable as a replacement for natural gas, the carbon dioxide must be removed. Carbon dioxide removal is conventionally accomplished by absorption in an aqueous solution of an organic base like monoethanolamine. The cost of this refining step is not very large in terms of the amount of refuse processed. The major portion of the cost is the capital cost of a compressor to raise the pressure of the gas before it enters the absorption tower. For a 100-ton-per-day plant and a ten-year compressor life, this would be about $0.17 per ton of refuse. After leaving the purification system, the gas would still be at a high enough pressure (perhaps 600 psi) to enter high-pressure gas mains supplying a metropolitan area. Thus the total cost of preparing a natural gas substitute from the digester gas would be on the order of $0.30 per ton of refuse.

Methane production may also contribute to agricultural waste management, particularly the management of livestock manures. Small installations have been described that can be built to produce household gas in rural areas.[75] However, these systems are designed to accept the wastes from only several animals per installation. The most successful large-scale combination of livestock waste management and methane extraction would use technology similar to that described for municipal wastes and will occur in places where very large confined livestock operations are located near a city or the pipe that connects a city with its natural gas sources. The amount of gas that may be produced from different kinds of manure is presented in Table 64.

TABLE 64

METHANE PRODUCTION

Livestock	Daily Manure Prod. per Animal		Volatile Solids Content, % of Dry Weight	Methane Prod. S.C.F. per Animal-Day (65% destruction of volatile solids; 7.15 S.C.F. CH_4 per lb of volatile solids destroyed)	Methane Prod., S.C.F. per Ton of Fresh Manure
	Wet Lbs	Dry Lbs			
Cattle	60	9	80%	33.4	1115
Swine	7	1.05	85%	4.14	1182
Poultry	0.25	0.0625	75%	0.218	1745

We can visualize a plant that extracts methane from cattle feedlot manure. The mass balances and total costs are presented in Figure 21. Application of this process to cattle manure is simpler than application to municipal refuse since the manure may be introduced to the digester as it is collected, particularly if a wet handling system is used for collection.

The digestion costs are estimated as before, from the cost of sewage sludge digestion in a digester of comparable volume. Dewatering and disposal of the sludge we assume to cost the same as in the example of refuse treatment. The total processing cost is seen to be $1.85 to $2.37 per ton of fresh manure. The largest fraction of the processing cost is for sludge dewatering and disposal. However, in a rural environment it may be possible to lagoon the wet sludge in an open pond or utilize its value as a fertilizer by spreading on cropland, substantially reducing these costs.

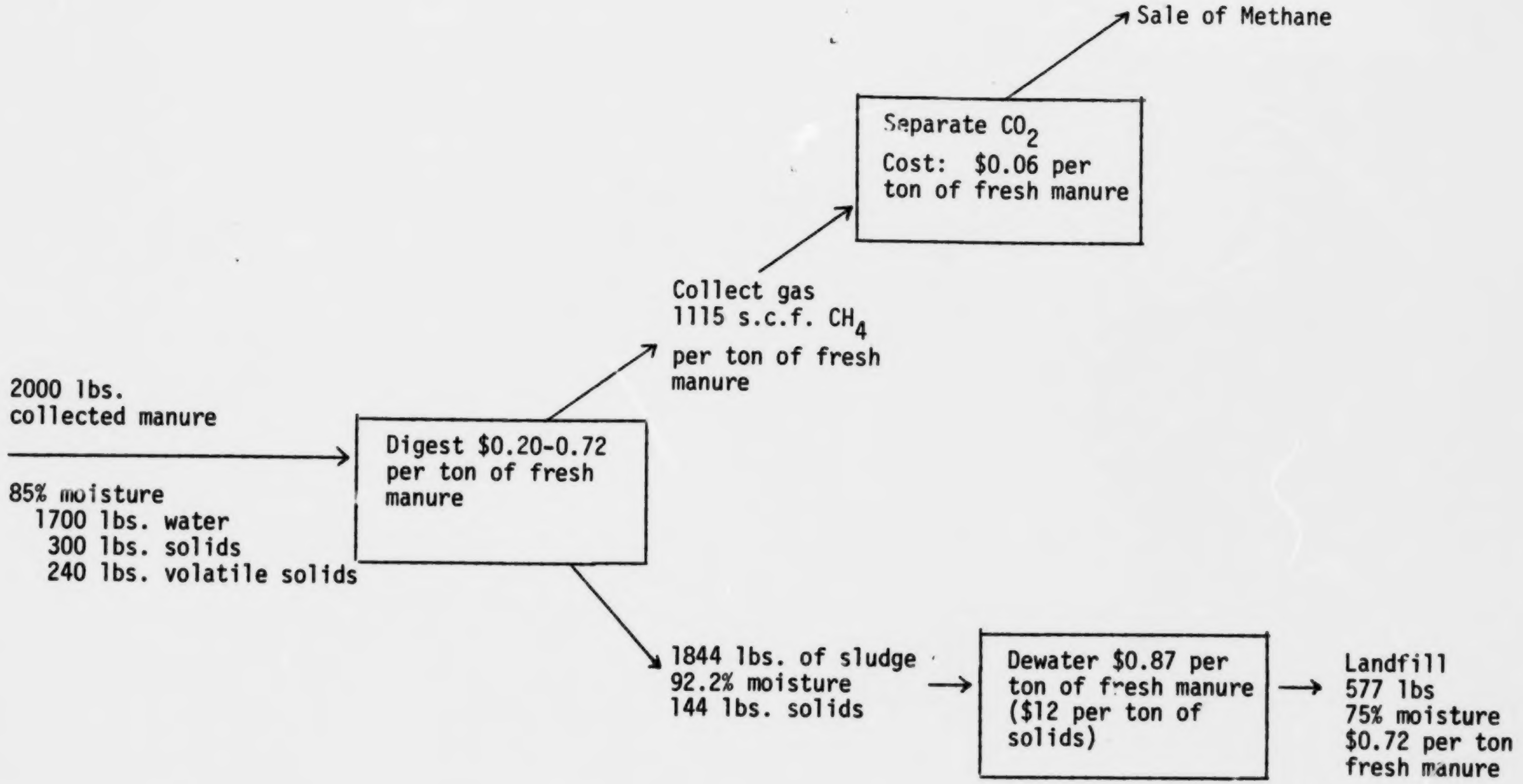


FIGURE 21

METHANE PRODUCTION FROM CATTLE FEEDLOT MANURE

Anaerobic digestion of sewage sludge is a conventional and widely practiced technology. The dewatering characteristics of sludge are particularly improved by the digestion process. However, because of the small solids content of sludge (4 percent), experience has shown that the quantity of digester gas produced is insufficient to warrant seeking a market for the gas beyond the internal uses of the sewage treatment plant.

ii. The Market for Combustible Gas Produced from Solid Wastes

Potential production of digester gas from municipal sewage and refuse and feedlot cattle manure represents the equivalent of approximately 3 to 4 percent of the U.S. natural gas requirements through 1990. For example, in 1970, sewage could contribute 0.13 percent, manure 0.52 percent, and refuse 2.9 percent approximately. An outline of these quantities is presented in Table 65.

The net quantity of digester gas available for sale will be somewhat less than the potential production because of the energy requirements of the production facilities for pumping and heating which in the case of sewage treatment plants is normally provided by use of the digester gas itself.

The most favorable market for sale of digester gas appears to be the gas distribution or retailing companies serving each municipal area. They are strategically located to make use of the gas produced from urban sewage and refuse with little required transportation and are actively seeking new sources of gas equivalent to natural gas. Gas produced from manure where feedlots are not adjacent to urban areas may be sold to natural gas transmission companies. These gas companies would require that the digester gas be concentrated and purified to nearly 100 percent methane with a heating value approaching 1000 BTUs per cubic foot from its condition as produced of containing 30 percent carbon dioxide and minor other impurities and a heating value of approximately 625 BTUs per cubic foot.

A secondary fragmented market is available for digester gas as produced by sale directly to individual industrial consumers.

Regional gas distribution companies appear to be interested and able to readily consume all of the digester gas likely to be produced. The value of the gas is currently approximately $0.35 per 1000 cubic feet of 1000 BTU gas. Direct industrial sales of gas as produced would command a price of perhaps one-half that per BTU, i.e., $0.11 per 1000 cubic feet of 625 BTU gas.

TABLE 65

POTENTIAL METHANE GENERATION FROM SOLID WASTES

A. FROM CATTLE FEEDLOT MANURE:

Year	Feedlot Cattle Population (thousands)	Potential Annual Production of Methane (billion cu ft)	Projected U.S. Natural Gas Requirement[a] (billion cu ft)
1970	11,800	144	24,483
1980	14,200	173	34,700
1990	16,500	201	46,686

B. FROM MUNICIPAL REFUSE:

Year	Population in Urban Areas (thousands)	Potential Annual Production of Methane (billion cu ft)	Projected U.S. Natural Gas Requirement[a] (billion cu ft)
1970	144,278	757	24,483
1980	192,215	1,010	34,700
1990	216,943	1,140	46,686

---

[a] Source: "Future Natural Gas Requirements of the U.S." Vol. 3, Future Requirements Agency, Denver Research Institute, September 1969.

iii. Evaluation

Net Cost. If municipal refuse is digested in metropolitan regions where natural gas is presently in use, the methane may be immediately sold to gas suppliers for 3.5¢ per therm, or, since methane has a heat content of 1000 BTU per s.c.f., $0.35 per 1000 s.c.f. Thus the 5250 s.c.f. of methane produced per ton of refuse is worth $1.84. The cost of extracting this resource, excluding penalties for residuals management, is $3.53 to $4.89 per ton of refuse. Residuals management would increase this cost by $1.89 to $2.36 for sludge dewatering, $1.96 for landfilling the sludge and the inert refuse. Thus, the total cost for management of both the refuse and sewage sludge from a city would be $8.01 to $9.84 less a return of $1.84, or $6.17 to $8 per ton of refuse. This estimate may be low because it is based on the cost of digesting sewage sludge, a more manageable substrate than slurried refuse.

The total cost of extracting methane from manure is $1.85 to $2.37 per ton of manure. The 1115 s.c.f. of methane produced per ton of manure could be sold to a transmission company for $0.39, thus the net cost would be $1.46 to $1.98 per ton of manure.

Ratings: methane extraction from municipal refuse: 4/8.
methane extraction from animal manure: 4/8.

Waste Reduction. In processing municipal refuse, one-fourth of the refuse is rejected before processing as inert. The sludge from the digester, after dewatering to 75 percent moisture, has a weight greater than three-fourths the weight of the original refuse. Thus the residual fraction, on the basis of weight, is about 1, and although there is a sufficiently large market for methane for this technology to be universally applied, the amount of waste reduction is actually zero.

In processing animal manure, the residual sludge has a mass, after dewatering to 75 percent moisture, of somewhat less than one-third that of the original manure. Thus, although the market for the methane is large, the reduction of the entire waste stream can only be 70 percent.

Ratings: methane extraction from municipal refuse: 1/8.
methane extraction from animal manure: 4/8.

Flexibility. Increase in plastics in municipal waste will limit the efficiency of this process. The methanogenic bacteria will be susceptible to uncontrolled toxins in the refuse. The resource is not storable.

The resource as produced outside of urban areas may not be easily fed into a distribution system.

Ratings: methane extraction from municipal refuse: 2/8.
methane extraction from animal manure: 2/8.

State of Development. State-of-the-art for sewage sludge. Extension to manure should be straightforward. Laboratory experiments have been completed with municipal refuse. Could be available in less than five years.

Ratings: methane extraction from municipal refuse: 4/8.
methane extraction from animal manure: 8/8.

Conservation of Natural Resources. Methane from municipal refuse could amount to about 3 percent of the natural gas now used. Methane from cattle manure could amount to about 0.5 percent of the natural gas now used.

Ratings: methane extraction from municipal refuse: 4/8.
methane extraction from animal manure: 4/8.

Weighted Totals:

Methane extraction from municipal refuse:
4x33 + 1x28 + 2x12 + 4x19 + 4x8 = 292/800.
Methane extraction from feedlot manure:
4x33 + 4x28 + 2x12 + 8x19 + 8x8 = 484/800.

c. Single-Cell Protein (SCP)

i. Process Description

Organic waste materials provide readily available substrates for the cultivation of the microorganisms that lead to their decay in a natural ecosystem. The growth of such microorganisms stabilizes noxious material and produces in the microbial cells protein that may be of high nutritional value. This resource has come to be known as single-cell protein (SCP), and its production may be a profitable means of utilizing and reducing wastes. The organisms frequently considered in this context are bacteria, yeast, and other fungi. These all require for their development a source of energy, as which soluble carbohydrates are ideal, and the nitrogen, phosphorous, potassium, and trace elements that commonly appear in wastes. When grown on wastes, these organisms depend upon the availability of the carbohydrates in cellulose, the predominant chemical compound in municipal and agricultural wastes.

The general term "cellulose" refers to both alpha cellulose and hemicellulose. Alpha cellulose predominates and is a polymer of anhydroglucose residues with degree of polymerization typically 3000. Hemicellulose appears frequently in wastes derived from wood, such as some kinds of waste paper, and is a polymer containing other pentoses and hexoses as well as glucose. Cellulase enzyme systems secreted by various microorganisms may attack either or both of these celluloses. A complete cellulose digesting system is believed to include an enzyme to disrupt the crystalline structure of cellulose, an enzyme to hydrolyze the polymer to monomers or dimers, and an enzyme to hydrolyze the dimers. Monographs by Siu and by Gascoigne list several hundred microorganisms that produce cellulases.[76,77] Several of these, ones that cause the highest rate of cellulose decomposition, have been selected by various investigators for application to waste substrates on a laboratory scale. However, SCP may also be derived from non-cellulolytic species, such as yeast, if wastes are initially hydrolyzed chemically, for example, with the use of acids or purified enzyme systems.

A process for the production of bacterial SCP from cellulose in waste sugarcane bagasse has been established in a pilot plant scale by the Department of Chemical Engineering at the Louisiana State University.[78] The process utilizes an aerobic mesophilic bacterium isolated from rotting sugarcane and identified as a member of the genus Cellullomonas.

In the Louisiana plant, bagasse is chopped to 1/8-inch particles, bathed in an alkali solution, sterilized, inoculated, and fermented with continuous aeration and agitation. Although it has been reported[79] that grinding the substrate below 1000 mesh size increases the rate of enzymatic attack, the Louisiana researchers felt it was too expensive to reduce particle size to this level on an industrial scale. The alkali treatment caused some decrystallization, delignification, and depolymerization. The optimum conditions of alkali treatment need to be established for each substrate, and for bagasse were 2 to 4 percent NaOH, 4 to 8 percent solids, 30 minutes to one hour duration. The fermentation broth contained 1 percent cellulose and was held in the fermenter for three hours at 95 degrees F, pH 7.0. The fermentation is exothermic and thus refrigeration was necessary to maintain the proper temperature for the mesophilic organism.

After fermentation the unhydrolyzed residue is settled out and the supernatent is acidified or mixed with a flocculating agent to precipitate the cells. The precipitated cells are centrifuged or drum dried. The cell mass produced was 50 percent of the weight of carbohydrate consumed, and the cells were found to have a protein content of about 50 percent. The amino acid balance was good, with lysine content higher than in the reference protein, established by the United Nations' Food and Agricultural Organization. However,

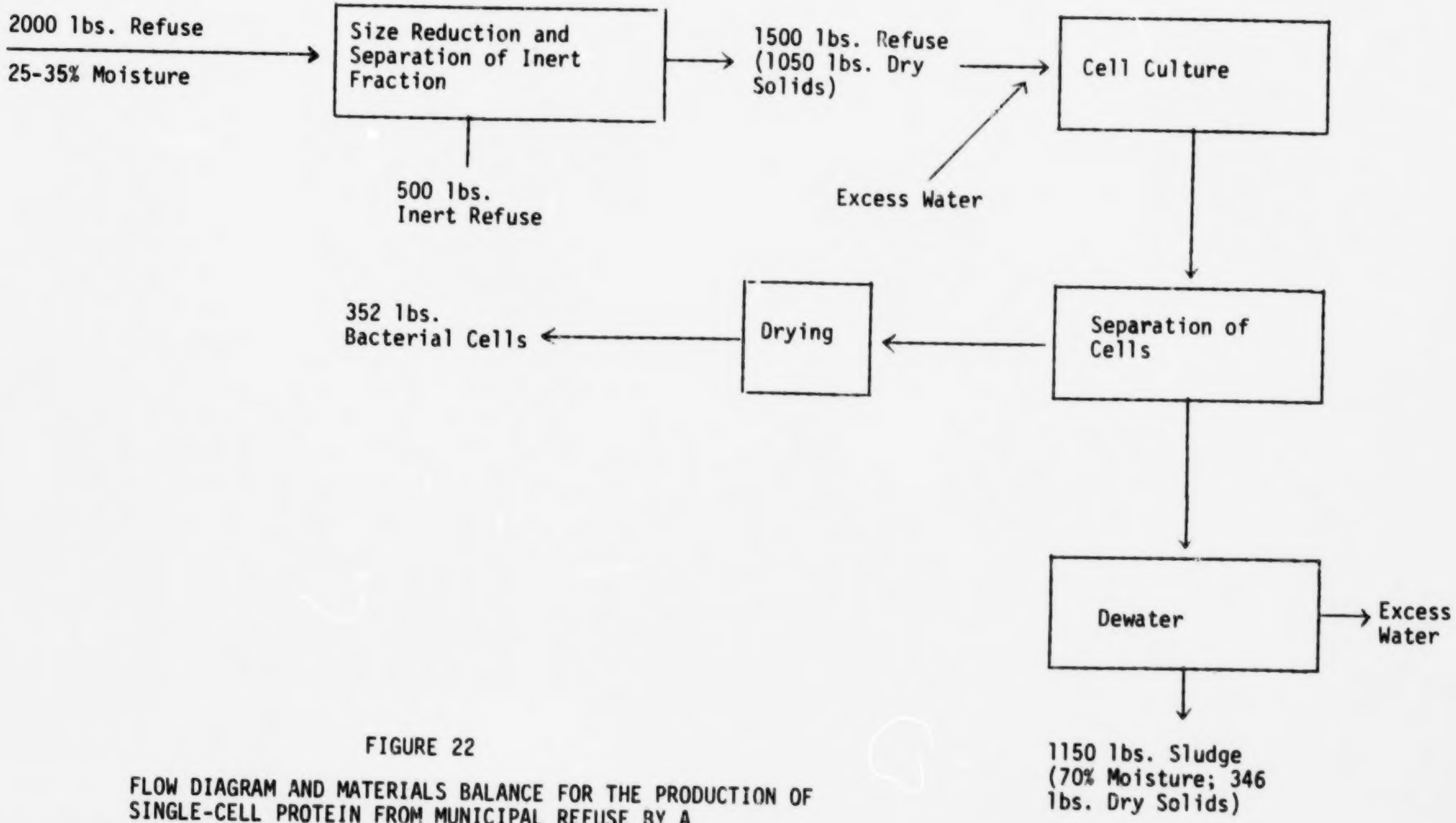


FIGURE 22

FLOW DIAGRAM AND MATERIALS BALANCE FOR THE PRODUCTION OF SINGLE-CELL PROTEIN FROM MUNICIPAL REFUSE BY A CELLULOLYTIC BACTERIUM the methionine content was lower than in the reference protein and was comparable to the methionine content of wheat. Methionine was found to be the limiting amino acid in feeding trials with rats. Not all the protein was utilized in the feeding trials and it was felt that homogenization or lysis of the cell walls might be a desirable step in processing Cellullomonas sp. as a feed.

By accident, the importance of symbiotic relationships in the culture of bacteria appeared in some of the pilot plant runs. When contamination of the fermentation broth occurred by a member of the genus Alcaligenes, the mixed culture exhibited better growth characteristics than the pure culture of either bacterium on the same medium, and final cell density was increased five-fold. It was believed that Alcaligenes consumed the hydrolysis product, cellobiose, that tends to inhibit cellulase activity. The value of such symbiotic relationships should undoubtedly be investigated in all SCP cultivation technologies.

Cost analyses based on current operating data from the LSU pilot plant indicate a production cost of 10¢ to 15¢ per pound of a product containing 50 percent protein. "It is rather optimistic at this time to say that the price will be further reduced by improving the production techniques."[80] The LSU process is adapted to a homogeneous agricultural byproduct that often has a non-negative value. The most valuable application of the pilot plant process as presently designed would be the production of animal feed in underdeveloped countries that have a surplus of cellulosic agricultural byproducts, but only small hydrocarbon resources that could be directed to SCP production. If applied to municipal wastes, the materials balance and flow diagram for the process would appear as in Figure 22.

At the General Electric Research Laboratories in Schenectady, researchers have felt that the chief obstacle in microbial conversion of wastes is the low rate of hydrolysis by mesophilic organisms.[81] Accordingly, they have undertaken a study of aerobic thermophilic bacteria. They collected organisms from compost heaps in New York and from anomalous hot earth areas in Yellowstone National Park and screened 64 cultures for cellulolytic activity. In several cultures "evidence for substrate utilization rates comparable to those in commercial fermentations was obtained." The cells collected were 50 percent protein and had an amino acid composition superior to zein (the dominant corn protein). Some other advantages that accrue from using thermophilic bacteria are that the fermentation broth is self-sterilizing and requires no refrigeration.

Meller, in a report to the Environmental Protection Agency,[82] has investigated the economics of cultivating a non-cellulolytic organism, yeast, on sugars produced by acid hydrolysis of the cellulose in waste materials. The production of baker's yeast or feed yeast from molasses is a well-practiced technology, so the novelty of Meller's proposed system is in the glucose production step. The cost of hydrolyzate sugars from treated municipal refuse is estimated at 2.87¢ to 4.70¢ per pound, depending upon plant size (see section 2b--hydrolysis). Meller provided an analysis of the aerobic fermentation costs of a plant processing 80 tons of paper per day (as would be found in 190 tons of as-received refuse) and extrapolations to larger plants. This data is in Tables 66 through 69. Meller points out that the manufacturing costs would be 5 percent less if a wood instead of steel fermenter were used, and 30 percent less if refrigeration were not necessary because of the availability of natural cooling water. (The 30 percent savings may be representative of the cost reduction when a thermophilic organism can be used instead of a mesophilic organism in SCP production.) Combining the hydrolysis costs that we developed in section 2b and fermentation costs taken directly from Meller's data, the total cost of yeast production is indicated in Table 70. The overall material balance and flow diagram for the application of this process to municipal refuse is presented in Figure 23.

Gray[83] and Litchfield[84] have written of the practice and potential of raising fungi for feed. Primarily the fungi imperfecti are considered in this context because they exhibit the most rapid growth. The best yields of fungal mycelium are obtained in submerged culture with continuous aeration and agitation, as in the culture of bacteria and yeast. However, fungal mycelium grows at a slow rate as compared to bacteria and yeasts, the doubling time being 4 to 12 hours. This leads to a necessity for thorough sterilization of substrate, large fermentation tanks, and generally higher production costs. No suitable fungi are thermophilic and thus cooling water or refrigeration is required. Crude protein values for fungi are low, 10 to 40 percent, and results in animal nutrition studies have been quite variable and for the most part disappointing. Part of this problem arises from the fact that the cell walls of imperfect fungi contain unavailable, non-protein nitrogen in the chitin that comprises 2.6 to 26.2 percent of the dry weight of the mycelium. Because of these problems, Litchfield concluded "it appears that fungal mycelium will be used as a pleasantly flavored food supplement for the foreseeable future rather than as a primary protein source."

Although only aerobic organisms are generally considered in the context of SCP production because of their high efficiency of conversion of substrate to cell material, there is some interest in developing an anaerobic system. Anaerobic populations are known to be strongly cellulolytic as in the rumen and in conventional sewage sludge digesters. The biomass that develops in anaerobic digestion is comparatively small because most of the energy of the carbohydrate substrate is released in the form of methane gas. However, an engineering process may be designed to utilize the

TABLE 66

EQUIPMENT COSTS FOR FERMENTATION OF HYDROLYZATE SUGARS

Item	Size	Material of Construction	Purchased Cost
Nutrient Makeup			
Metering Pumps	50 GPH	Iron	1,200
Hydrolyzate pump	100 GPM	Cast Iron-Centrifugal	1,000
Ammonia metering equip.		Iron	800
Air Supply			
Air Compressor	11,500 CFM	Iron-Centrifugal	126,000
Fermenter	570,000 Liters	Iron-Centrifugal	145,000
Cooling			
Refrigeration System	1000 tons	--	155,000
Broth circulation pump	42 HP	Iron-Centrifugal	2,000
Cooling Tower	17×10^6 Btu/hr		80,000
Recovery and Washing			
Centrifuges, continuous	100-150 GPM		54,000
Pumps	100 GPM	Cast Iron-Centrifugal	3,000
Drying and Packaging			
Dryers-Double Drum	12,400#/hr		86,000
Hammer Mill	1 ton/hr		10,000
Storage	20 tons	Aluminum	15,000
Packaging System			5,000
		Total Equipment Cost	$684,000

NOTE: Fermentation plant accepts hydrolyzate sugars from a plant processing 133 tons of dry refuse per day, and is operated 3 shifts per day. Cost figures dated 1964.

Data from: Meller, F.H., "Conversion of Organic Solid Wastes into Yeasts - An Economic Evaluation," U.S. Environmental Protection Agency, Rockville, Md. 1969.

TABLE 67
ESTIMATE OF TOTAL CAPITAL INVESTMENT: FERMENTATION PLANT

Item and Basis for Estimation		
1.	Purchased equipment-delivered (P.E.C.)	684,000
2.	Equipment installation (including instrumentation) 43% P.E.C.	294,000
	Installed equipment cost	978,000
3.	Piping (Including insulation) - 2% P.E.C.	184,000
4.	Electrical installations-15% P.E.C.	105,000
5.	Buildings. (including services) - 35% P.E.C.	239,000
6.	Yard improvements - 10% P.E.C.	68,000
7.	Service facilities - 35% P.E.C.	239,000
8.	Land - 4.8% P.E.C.	33,000
9.	Total physical plant cost	1,846,000
9.	Engineering and construction - 40% P.E.C.	274,000
	Direct plant cost (D.P.C.)	2,120,000
10.	Contractors fee - 7% D.P.C.	148,000
11.	Contingency - 15% D.P.C.	318,000
	Fixed capital investment (F.C.I.)	2,586,000
12.	Working capital (total operating cost for 30 days)	102,000
	Total capital investment	2,688,000

NOTE: Fermentation plant accepts hydrolyzate sugars from a plant processing 133 tons of dry refuse per day, and is operated 3 shifts per day. Cost figures dated 1964.

Data from: Meller, F.H., "Conversion of Organic Solid Wastes into Yeasts - An Economic Evaluation," U.S. Environmental Protection Agency, Rockville, Md., 1969.

TABLE 68

ESTIMATED MANUFACTURING COST: FERMENTATION PROCESS

Item	Units/day	Cost	Daily Cost
A. Direct production cost			
1. Raw Materials (excluding cost of sugar)			
Ammonia, anhydrous	1.91 tons	$92.00/ton	175.80
Phosphoric acid, 53%	1.19 tons	51.00/ton	60.60
Potassium chloride, 95-99%	0.78 tons	30.00/ton	23.40
2. Utilities			
Electricity	42,700 kw-hr	0.007/kw-hr	299.00
Steam	360,000#	0.52/1000#	187.30
Process water	221,000 gal.	0.25/1000 gal	55.20
3. Operating labor 2 men/shift	48 man-hrs	3.00/man-hr	144.00
4. Supervisor (Use Hydrolysis Plant Supervisor)			--
5. Fringe benefits 15% hourly wage			21.60
6. Operating supplies 10% of labor			14.40
7. Maintenance & Repairs 10% FCI/yr.			719.00
Direct Production Cost			1,700.30
B. Fixed Charges			
1. Depreciation - 12 yr. plant life zero salvage value, = 8-1/3% FCI/yr			600.00
2. Local Taxes - 2% FCI/yr			144.00
3. Insurance - 1% FCI/yr			72.00
Fixed Charges			816.00
C. Plant Overhead - 70% operating labor, supervision and maintenance labor			352.00
D. General Expenses			
1. Administrative 15% of operating labor, supervision and maintenance labor			75.50
2. Distribution and selling cost (not applicable)			
3. Research and development 5% product cost			170.00
4. Interest 4% TCI/yr			299.00
General Expenses			544.50
Total production cost			3,412.80
Production Cost/# Yeast= $0.092/# (excluding cost of sugar)			

NOTE: Fermentation plant accepts hydrolyze sugars from a plant processing 133 tons of dry refuse per day, and is operated 3 shifts per day. Cost figures dated 1964.

Data from: Meller, F.H., "Conversion of Organic Solid Wastes into Yeasts - An Economic Evaluation," EPA, Rockville, Md., 1969.

TABLE 69

DAILY MANUFACTURING COST FOR YEAST AT VARIOUS PLANT CAPACITIES

Capacity: Tons of Refuse Per Day	190	250	500	834	1,670
Fixed Capital Investment	2,586,000	4,005,000	6,515,000	9,050,000	14,740,00
A-1 Raw Materials	259.80	487.00	974.00	1,558.00	3,116.00
A-2 Utilities	531.50	995.00	1,990.00	3,180.00	6,360.00
A-3 Operating Labor	144.00	144.00	144.00	144.00	144.00
A-4 Supervisor	-	-	-	-	-
A-5 Fringe Benefits	21.60	21.60	21.60	21.60	21.60
A-6 Operating Supplies	14.40	14.40	14.40	14.40	14.40
A-7 Maintenance & Repairs	719.00	1,114.00	1,810.00	2,520.00	4,100.00
B-1 Depreciation	600.00	930.00	1,510.00	2,100.00	3,420.00
B-2 Local Taxes	144.00	223.00	362.00	504.00	820.00
B-3 Insurance	72.00	111.50	181.50	252.00	420.00
C Overhead	352.00	491.00	734.00	984.00	1,535.00
D-1 Administrative	75.50	105.30	157.20	211.00	329.00
D-2 Dist. & Selling	-	-	-	-	-
D-3 R&D	170.00	293.00	500.00	660.00	1,160.00
D-4 Interest	299.00	465.00	754.00	1,050.00	1,715.00
Daily Prodn. Cost	3,412.80	5,395.00	9,153.00	13,200.00	23,155.00
Prodn./day(#/day)	37,000	69,400	138,500	231,500	463,000
Prodn. cost/# Yeast (Excluding cost of sugar)	9.22¢/#	7.78¢/#	6.60¢/#	5.70¢/#	5.00¢/#

SOURCE: Meller, F.H., "Conversion of Organic Solid Wastes into Yeasts - An Economic Evaluation," U.S. Environmental Protection Agency, Rockville, Md., 1969.

TABLE 70

COST OF YEAST PRODUCTION FROM MUNICIPAL REFUSE

Plant Scale (tons per day of dry refuse containing 60% cellulose)	133	250	500	834	1670
Net Production Cost of Hydrolyzate Sugar (¢/pound of sugar, 1968)	4.70	4.05	3.47	3.18	2.87
Cost of Sugar per Pound of Yeast Produced (50% utilization in conversion to yeast) (¢/pound of yeast)	9.40	8.10	6.94	6.36	5.74
Cost of Fermentation (¢/pound, 1968)	9.22	7.78	6.60	5.70	5.00
Net Cost of Yeast Production (¢/pound, 1968)	19.62	15.88	13.54	12.06	10.74

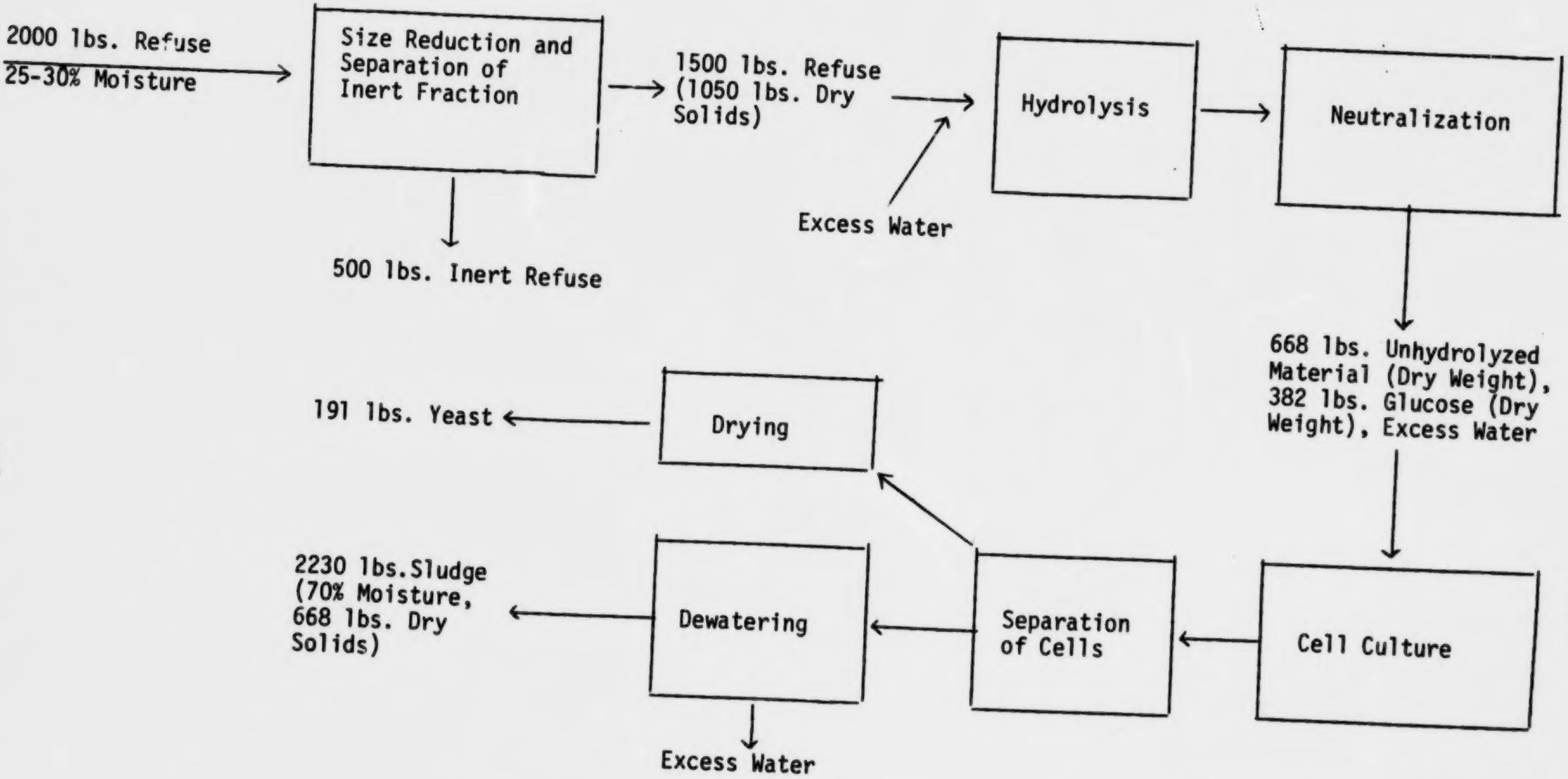

2000 lbs. Refuse
25-30% Moisture
Size Reduction and Separation of Inert Fraction
500 lbs. Inert Refuse
1500 lbs. Refuse (1050 lbs. Dry Solids)
Excess Water
Hydrolysis
Neutralization
668 lbs. Unhydrolyzed Material (Dry Weight), 382 lbs. Glucose (Dry Weight), Excess Water
Cell Culture
Separation of Cells
Drying
191 lbs. Yeast
Dewatering
Excess Water
2230 lbs.Sludge (70% Moisture, 668 lbs. Dry Solids)

FIGURE 23

FLOW DIAGRAM AND MATERIALS BALANCE FOR THE PRODUCTION OF SINGLE-CELL PROTEIN FROM MUNICIPAL REFUSE BY A NON-CELLULOLYTIC YEAST methane so produced as an energy source for process power. At least one corporation has been investigating the feasibility of such a system for the destruction of feedlot wastes and production of a protein feed that can be used on the same feedlot that generated the waste substrate. Detailed information on this system is confidential and not currently available. Leatherwood at North Carolina State University, Raleigh, is studying the basic microbiology of anaerobic, cellulolytic bacteria as they would thrive in batch, semi-continuous and continuous fermenter systems.

The technology for growing single-cell protein on manure would be very similar to that used for municipal waste. Anthony has reported laboratory-scale cultivation of yeast on hydrolyzed cattle manure.[85] Feeding trials on rats with the yeast product were not successful because of the high sodium content of the feed that was introduced by neutralizing the acid with sodium hydroxide. That problem will not be insurmountable, and in the future yeast cultivation on manure may appear to be a desirable waste management scheme if it is found that the unconverted residual fiber and other compounds in the manure can be recycled to the animal along with the yeast. Two research projects have been recently initiated at the Northern Utilization Research Division of the Agricultural Research Service in Peoria to survey all possible means of preparation of a protein-enriched feed from solid and liquid feedlot wastes.[86,87] These projects will emphasize growing SCP from indigenous microorganisms and selected cultures.

ii. The Market for Microbial Single-Cell Protein

The mass market for microbial single-cell protein is seen as a high-protein feed concentrate, supplementing livestock feed grains to improve the overall protein content of normal grain feeds. The most important concentrates both in terms of protein content and the volume used each year have become the oilseed meals and animal proteins. The two most important oilseed meals in use in the United States are soybean meal and cottonseed meal, containing respectively 45 to 50 percent protein and 40 to 42 percent protein on a crude basis. Single-cell protein derived from municipal waste or animal manure, perhaps supplemented to alleviate certain amino acid deficiencies, could be an acceptable substitute for the traditional high-protein feeds.

Table 71 provides a forecast to the year 1990 of probable animal feed concentrates consumption in the United States. These estimates relate primarily to the number of animal units expected to be consuming feed in the years shown, starting for comparative purposes with the animal feed consumption in 1960. Over the 30-year period, the consumption of supplemental feed is expected to increase from 18.7 percent of the total in 1960 to only 19.7 percent

TABLE 71

FORECAST OF ANIMAL FEED CONSUMPTION IN THE UNITED STATES, 1960-1990
(Millions of Tons)

Item	1960	1970	1980	1990
Feed Grains	121.80	144.90	176.00	200.00
High-Protein Supplements:				
Soybean Meal	8.84	13.46	17.80	22.85
Other Oilseed, Animal and Grain	7.95	7.81	8.95	8.55
Total High Protein	16.79	21.27	26.75	31.40
Other Processed Feeds	11.24	13.31	15.85	17.80
Total Feed	149.83	179.48	218.60	249.20

Sources: 1980 and 1990 estimated. 1960 and 1970 derived from USDA Economic Research Bulletin No. 410, Feed Statistics Through 1966, as Supplemented through 1969, Feed Situation, November 1971, and certain unpublished data.

in 1990. Between 1960 and 1990, the consumption of soybean meal is expected to rise from 8.8 million tons to 22.9 million tons, or by 158.5 percent.

Table 72 shows high-protein feed prices assembled by the United States Department of Agriculture for the feeding years (October through September) 1970 and 1971. These are annual averages.

The price which farmers might have paid for 50 percent soybean meal is not collected by the Department of Agriculture although farmers do buy that grade. An equivalent price, however, is readily developed from the price differentials between 44 percent and 50 percent soybean meal in the wholesale markets which, for twelve identical markets in 1971, were 4.44¢ and 4.78¢ per pound, respectively. On the basis of this ratio, the price paid directly by farmers for 50 percent soybean meal would be about 6.12¢ per pound. For evaluation purposes, this will be taken as the market price of concentrated microbial cells which also will have a 50 percent protein content.

TABLE 72

COMPARATIVE PRICES OF SELECTED HIGH-PROTEIN FEEDS, 1970 AND 1971

(in Cents per Pound)

High Protein Feed	Prices Paid by Farmers		Average Prices Paid at Wholesale			
			1970		1971	
	1970	1971	No. Mkts	Price	No. Mkts	Price
Prices Available Both Ways:						
Soybean meal - 44% protein	5.52	5.69	16	4.45	15	4.46
Cottonseed meal - 41% protein	5.26	5.54	13	3.98	12	4.20
Prices Available Wholesale Only:						
Soybean meal - 50% protein			14	4.88	12	4.78
Meat meal - 50% protein			11	5.34	11	4.94
Fish meal - 60-65% protein			5	9.81	6	8.73

Source: Feed Market News, Consumer and Marketing Service, U.S.D.A.

SCP produced on waste materials may in the future be competing as an animal feed with SCP produced on hydrocarbon substrates. The technology of the latter process is being rapidly developed.[88] However, SCP from cellulose has an advantage in that it will not be as difficult to separate the product from the substrate and, if the separation is not complete, the cellulose residue that may appear in the feed will not be objectionable as will any amount of mineral oil in a feed grown on hydrocarbons.

iii. Evaluation

The evaluation ratings presented here pertain generally to the production of single-cell protein by either cellulolytic organisms (bacteria) or non-cellulolytic organisms (yeasts), since the different technologies involved have similar characteristics from the viewpoint of waste management.

Net Cost. From the data in Table 70, we can interpolate that the processing cost of yeast in a plant that accepts 400 tons per day of refuse (300 tons per day dry weight) is about 15¢ per pound of yeast. Updating to 1972, this cost would be about 17¢ per pound of yeast. Since 191 pounds of yeast can be derived from a ton of refuse (see Figure 23), the cost of processing one ton of refuse is $32.40. The sale of the yeast would return $11.80 less an estimated marketing and distribution cost of $2.50. The net cost, then, for municipal refuse is $32.40 + $2.50 - $11.80 = $23.10 per ton.

Although the processing cost per pound of protein is roughly the same with bacteria as with yeast, the net cost of treating refuse with cellulolytic bacteria would be greater because more protein is produced per ton of refuse.

The cost of processing single-cell protein from animal manure is estimated, taking into consideration that little initial preparation would be required with manure, and assuming that basic processing costs depend upon the cellulosic content of the feed. Processing cost: $9 per ton of manure to produce yeast SCP. Return from sale of protein: $4. Because the finished product may be consumed by the producers of the raw material, marketing and distribution costs are negligible. Net cost: $5 per ton.

Ratings: cultivation of single-cell protein on municipal waste: 1/8.
cultivation of single-cell protein on animal manure: 2/8.

Waste Reduction. The amount of single-cell protein that may be produced from municipal refuse is comparable to the market for soybean meal, currently about 13 million tons per year. Since one person generates one ton of refuse per year, and 191 to 352 pounds of SCP protein may be produced from that ton of refuse, the high-protein feed market would be saturated by the extraction of protein from the wastes of 74 to 136 million persons. Because widespread application of this technology would thus require complete penetration of the high-protein feed market, which would be difficult in face of the current competition, the size of this market should be considered somewhat limiting.

Furthermore, a serious drawback in extracting single-cell protein from refuse, from the viewpoint of waste management, is the large residue remaining after processing. Since dewatering the residue below 70 percent moisture would generally require expensive thermal drying, the output sludge of a yeast culture plant would be comparable, in weight, to the input refuse. With the more efficient cellulolytic bacteria, the sludge would weigh more than 50 percent of the weight of the input refuse. When the added burden of the separated inert refuse is considered, the overall waste reduction is seen to be quite small (see Figures 22 and 23).

We estimated that cellulose retrievable for ethanol production (see section 2b) was generated at the rate of 4.0 pounds per animal-day in cattle manure. At most, 90 percent of this might be converted to soluble carbohydrate by microbial enzymes, or 60 percent by acid hydrolysis. If the conversion of soluble carbohydrate to cell mass is 50 percent efficient by weight, then SCP may be produced at a rate of 1.20 to 1.80 pounds per animal/day. The current demand for soybean meal could therefore be satisfied by the protein derived from the wastes of 40 to 59 million head of cattle, so the size of the market would not be limiting in the application of this technology to feedlot wastes. Furthermore, the residue after processing may be small if unreduced fiber or other constituents of the manure are included in the feed mixture prepared.

Ratings: cultivation of single-cell protein on
  municipal waste: 1/8.
cultivation of single-cell protein on
  animal manure: 4/8.

Flexibility. The cultivation of microorganisms on municipal refuse will be less efficient if the plastics content of refuse increases, and is susceptible to uncontrollable toxins that may appear in the refuse. The user of the resource is remote from the source of refuse. The marketing situation is risky as the producer will be selling into a weak market in an industry with overcapacity.

On the other hand, cultivation of single-cell protein on animal manure proves desirable in terms of all factors considered in evaluating flexibility. In particular, the feedlot owner/manure processor can control the characteristics of the waste stream, and all marketing problems are eliminated as the feed is generated right next to the animals that will eat it.

Ratings: cultivation of single-cell protein on municipal waste: 1/8.
cultivation of single-cell protein on animal manure: 8/8.

State of Development. The cultivation of single-cell protein on waste materials and the feeding of the protein to animals has been done only on a laboratory scale. However, components of the technology are state-of-the-art, and thus a complete system could be available in less than five years. Some delay must be anticipated in completing appropriate tests to gain FDA approval.

Ratings: cultivation of single-cell protein on municipal refuse: 4/8.
cultivation of single-cell protein on animal manure: 4/8.

Conservation of Natural Resources. In 1970 there were 13×10^6 tons of soy protein produced from soybeans grown on 42×10^5 acres. If single-cell protein were grown on municipal refuse, a major fraction of this land could be diverted to other uses; and if the protein were grown on animal manure, about one-fourth of this land could be diverted to other uses.

Ratings: cultivation of single-cell protein on municipal waste: 2/8.
cultivation of single-cell protein on animal manure: 2/8.

Weighted Totals:

Cultivation of single-cell protein on municipal waste:
1x33 + 1x28 + 1x12 + 4x19 + 2x8 = 165/800.
Cultivation of single-cell protein on animal manure:
2x33 + 4x28 + 8x12 + 4x19 + 2x8 = 366/800.

d. Feeding Wastes to Livestock

Various proposals for the utilization of wastes as animal feeds were examined, including the feeding of manures to livestock and fish, and the feeding of residential and institutional garbage to swine. Although some of these proposals appear practical for special situations, none of them can be applied on a large enough scale to make a significant impact on the total burden of combustible solid waste. Therefore, instead of a complete evaluation of each proposal, a general discussion is present here in which the various limitations of these proposals are pointed out.

i. Animal Manures as Livestock Feeds

The composition of livestock manures indicates that the nutritional values of feeds are not completely utilized on a single pass through animals. Furthermore, the initial value of feeds may be supplemented by the development of microorganisms and their metabolities in the digestive tracts of ruminant animals and some of these benefits are not completely utilized before they are lost with the manure. One possible means of using these residual nutritional values is to use manures as a feed ingredient. A portion of a manure can be refed to the original producer or the manure can be fed to another livestock animal, anticipating that a different digestive system may find a different way of utilizing the discarded material. Along these lines the most desirable and feasible refeeding schemes discussed in the literature involve refeeding of poultry and cattle manures, the feeding of poultry manure and litter to cattle and sheep, and the feeding of cattle manure to sheep.

Before implementation of any refeeding scheme, particular attention should be paid to the dangers of concentration of, or exposure to, toxic compounds in the feed-manure mixtures such as arsenicals or antibiotics. If manure is completely refed within a single group of animals, then the levels of undigested compounds will increase without limit, or until a threshold is reached beyond which the compound is incorporated in the animal's tissues, milk or eggs, presenting a hazard to the animal or its human consumer. Where toxic compounds are eliminated, there will probably still be a buildup of inert material that cannot be absorbed. Thus, it can be anticipated that all successful refeeding regimes will produce an excess quantity of manure that will demand alternate disposal or utilization. But even when a portion of the manure is continuously disposed of, the increase in the steady-state levels of trace compounds in the feed mixture can be quite large.

Since these increases can be anticipated, the concentration of feed additives can be corrected for by the livestock farmer or feed supplier when the conventional feed is mixed. However, any toxic elements that are not deliberately added, such as heavy metals or pesticide residues, cannot be corrected for. Furthermore, the compound may undergo chemical changes in the animal's intestine. Every degradation product of feed additives will have to be identified before a refeeding regime can be implemented.

The problems with feed additives may be even greater if manure from one kind of livestock is fed to another as the compound may influence different animals in different ways. The Food and Drug Administration does not currently sanction feeding of poultry litter or feces to ruminants because of the potential public health hazard from disease organisms and drugs. The Department of Agriculture in 1965 made a policy statement unfavorable to the use of poultry litter as feed for beef cattle because of possible toxicity to ruminants of drugs, pesticides and feed additives, hardware in litter, transfer of diseases and molds, and digestive disturbances attributed to litter feeding.[89,90] More recently, however, the Department has encouraged research on waste recycling.

In a final economic analysis of refeeding regimes it would probably be necessary to balance the cost of withdrawing some feed additives against the benefit of reducing the amount of feed required. However, here we will indicate only the potential benefits in terms of reduced feed consumption and waste disposal burden of refeeding schemes that are currently being researched and appear feasible.

Utilization of Poultry Feces. Feeding trials on laying hens and broilers have been conducted with mixtures of conventional feeds and poultry feces.[91,92] To render manure-grain mixtures palatable and free from pathogenic organisms, most of the water must be removed from fresh manure, and the manure must be sterilized. Fontenot[93] compared various methods for sterilization of broiler litter, such as autoclaving at 116 degrees C under steam pressure from 30 to 120 minutes, heating in a forced-draft oven at 100 degrees and 150 degrees C for 4 to 48 hours, fumigating with ethylene oxide, treating with beta propiolactone from periods of 30 minutes to 24 hours, and, finally, piling in deep stacks for 30 to 120 days to encourage normal heating of the litter. The only effective method was found to be heating in a forced-draft oven at 150 degrees C for at least 4 hours. Thus it will probably be most economical to combine both partial moisture removal and sterilization in a single thermal drying step. However, there are several possible approaches involving such a procedure. First, the manure may be removed fresh from the poultry house (75 percent moisture) and dried in one step with fossil fuel heat to 10 percent moisture (further drying produces an undesirably dusty product). Apparatus for single-step drying is commercially operated to produce soil conditioner from poultry manure for a total cost of $5 to $6 per ton of fresh manure ($18 to $22 per ton of product).

Bressler[94,95] at Pennsylvania State University has found that it is more economical to air-dry the manure in the poultry house with large fans and apparatus on the floor below the cages to agitate the droppings before applying a final sterilization and drying from 30 percent to 10 percent moisture. The drying costs encountered at Penn State were $1.67 per ton of fresh manure ($6 per ton of product) for fuel and electricity and a capital investment of $2700 day/ton. If the capital cost is amortized for 20 years at 10 percent interest, it is equivalent to $0.87 per ton of fresh manure ($3.13 per ton of product). Thus the capital and energy costs were $2.54 per ton of fresh manure. Labor and other overhead costs were not estimated by Bressler, but should increase the total cost to at least $3 per ton of fresh manure ($10.80 per ton of product).

Calvert[96] has suggested that cultivation of housefly larvae in manure could encourage air-drying to 30 percent moisture before a final moisture removal and sterilization step. The harvestable housefly protein returns a credit of $3.20 to $6.40 per ton of fresh manure; however, it will not be clear whether this will pay for the cultivation and drying process until a suitable automated design is determined for the cultivation of large quantities of larvae. It is anticipated that the cost of a drying scheme based on the housefly will be intermediate between the cost of air-drying at Penn State, and conventional thermal drying.

It has been suggested that by assisting thermal drying by using microwave power to bring moisture to the surface of manure solids, the cost of one-step thermal drying can be considerably reduced, at least by a factor of two.

To summarize the costs of preparing a dry, sterile feed supplement from poultry manure (exclusive of any screening, storage or mixing costs that may be necessary), the current cost is $5 to $6 per ton of fresh manure, and future technologies may reduce this cost to as little as $2.75 per ton.

In experimental trials it has generally been found that feed efficiency is inversely related to the amount of manure included in the diet. However, when incorporated at only 10 percent of the diet, the manure seems to increase feed efficiency and the productivity of laying hens. This increase in efficiency is presumed due to presently unknown stimulants in the manure since the protein content at 10 percent and low metabolizeable energy of the manure indicate it should be less nutritious than the corn it replaced in the experimental diets.[97]

Feeding manure at higher levels, up to 40 percent of the diet, has not produced any deleterious effects in experimental birds, but feed efficiencies are depressed and there is no saving in the amount of conventional grain fed. Since the average broiler or laying hen consumes 0.25 pounds of feed per day and reduces this to 0.0625 pounds of manure (dry weight), refeeding at a realistic and advantageous level of 10 percent of the diet will leave 0.0375 pounds of manure per bird to be disposed of, a reduction of 40 percent in the waste burden.

In experimental trials, the manure has directly replaced a grain such as corn. Estimating then a value of 2¢ a pound for the dry manure, each ton is worth $40, which is $11.11 per ton of fresh manure. However, this is true for only 40 percent of the manure, and the other 60 percent of the manure must still be managed. If the drying cost to the farmer is $3 to $6 per ton of fresh manure, then he profits $5 to $8 on each ton of manure he dries, up to 40 percent of his manure. He may use this profit to subsidize the disposal of the other 60 percent of the manure. This subsidy could amount to $3.33 to $5.34 per ton of manure yet to be managed. This subsidy may be sufficient to cover the cost of drying the unused manure, in which case it could be distributed to markets off the poultry farm.

A large potential market for the dried manure away from the poultry farm is as a feed supplement for ruminant animals. In this regime the manure will probably be looked upon as a nitrogen source containing about 5 percent nitrogen, or 30 percent crude protein, most of the non-protein nitrogen being urea and ammonia, with perhaps some consideration of its true protein content of 10 percent. Feeding trials with sheep have been undertaken.[98,99] These studies indicated that feed mixtures in which dried poultry manure was included were acceptable to sheep and the "protein of the dried wastes was slightly less digestible than that of soybean meal, but had a biological value equal to that of soybean meal for growing sheep."[100] Feeding trials with cattle have also been undertaken.[101,102,103] These studies indicated that as with sheep, poultry manure has a potential as a source of nitrogen, but feed efficiencies are lower than with soybean meal. For example, in one trial, a corn-corn silage feed was supplemented to 12 percent crude protein. The nitrogen supplements, and the resulting feed-per-gain ratios, were: dried poultry feces, 10.43; one-half feces/one-half urea, 7.31; one-half feces/one-half soybean meal, 8.14; urea, 7.23; soybean meal, 6.96. These data indicate that dried poultry feces perform almost as well as urea as a crude protein, or, more appropriately, a non-protein nitrogen source.

Evaluating poultry manure as a non-protein nitrogen source, we can assign a value to it in terms of the price of urea, 5¢ per pound. Urea is 45 percent nitrogen and poultry manure is 5 percent nitrogen. Thus when used as a nitrogen supplement, nine pounds of manure will replace one pound of urea, and the value of the manure will be 0.56¢ per pound, or $11.50 per ton of dry manure. However, if the true protein in poultry manure (10 percent) was valued as highly as soy protein at 14¢ per pound, then the manure would be worth 1.4¢ per pound, or $28 per dry ton. In England caged layer manure is now being marketed as feed under the name TOPLAN (crude protein 26.6 percent) for $28.80 per ton. The British Agricultural Research Council has suggested the following feeding rates: for milking cows, 25 percent TOPLAN to 75 percent barley; for beef and sheep production herds, 50 percent TOPLAN to 50 percent barley. The potential demand for the non-protein nitrogen in manure is quite large. In a cattle feed with 12 percent crude protein, current practice permits replacing up to one-third of the crude protein, or 4 percent of the feed, with urea nitrogen. The urea has a crude protein equivalent of 285 percent, so the feed mixture may contain 1.4 percent urea by weight. Thus a typical feed will be supplemented by 0.28 pounds of urea, or 2.52 pounds of poultry manure, for each 20 pounds of feed, the amount eaten by an average cow in a day.

Six and a half million tons of dried poultry manure is potentially available from all the chickens in the United States each year, before refeeding schemes are implemented. If fed as a non-protein nitrogen source at the rate of 2.5 pounds per cow-day, all of the manure would be absorbed by 13 million head of cattle, 13 percent of America's herds.

Utilization of Poultry Litter. Poultry litter is the waste mixture of about half peanut hulls, rice hulls, sawdust, shavings, bagasse, oat hulls or straw and half feces from birds raised on open floors covered with these materials. Thus litter is a combination of a suitable roughage feed and a non-protein nitrogen source--the poultry feces. The proximate analysis of used litter indicates a crude protein value of 20 to 25 percent, comparable to undiluted feces (17 to 30 percent crude protein, depending on conditions of drying). This high nitrogen content is presumed due to additional contributions of nitrogen from wasted feed particles, bacterial synthesis, and to a minor extent the direct contribution of the base material.[104] The moisture content of litter is 25 to 30 percent, considerably drier than fresh manure; thus moisture removal in preparation of litter as a feed for ruminants would be less expensive on a per-dry-ton basis.

The value of litter as a ruminant feed would probably be comparable to dried feces as it would be desired as a nitrogen source.[105] It will be easier to market the litter if the base material is a familiar roughage such as peanut hulls or straw rather than wood shavings. Although a refeeding scheme based on litter may appear more economical than one based on feces, the advantages of raising and keeping chickens in cages are leading to the decline of the use of litter in poultry farming.

Refeeding Cattle Manure. The feeding of cow feces to other animals is not a new concept. In the 1940's cow manure was looked upon as a source of B-complex vitamins of value to poultry and swine. Today these vitamins are generally supplied by other means. However, ruminant feces remain a potential source of undigested cellulose of which 5 to 70 percent might be digested upon recycling of the feces.[106]

Anthony[107,108] has felt that refeeding feedlot manure in manure-grain mixtures (2:3 ratio) provides a means of partially recovering undigested nutrients while in addition providing an incentive for daily cleaning of feeding pens, thus reducing odor and fly problems. The manure, he visualizes, is collected from concrete floors daily and mixed, wet and without further treatment, with grain for the next day's feeding. Although feeding trials under such a regime resulted in improved feed efficiencies, Anthony felt the system lacked flexibility since only half of the manure collected daily could be fed back to the cattle which generated it, and the manure could not be satisfactorily stored. A more flexible system developed by Anthony[109] involves combining fresh manure with ground grass hay (57:43, by weight) and then storing the mixture in a silo until needed. The ensiled manure-hay mixture, for which Anthony has introduced the term "wastelage," was found in feeding trials to be a satisfactory, complete ration for beef and sheep breeding herds. With ewes, feeding wastelage instead of hay resulted in a saving of 44 percent of hay, 1.75 pounds of hay saved per ewe-day. The amount of feedlot manure necessary to effect this saving was 2.9 pounds, so the manure could be valued as a sheep feed at 60 percent the value of grass hay, perhaps $15 per ton. For feeding beef cows, Anthony found wastelage to be of equal value to corn silage. He concluded that feeding wastelage from fattening steers is "the most promising of all known feeding regimes for situations where beef brood cows are managed in conjunction with dry lot finishing of slaughter cattle."

The necessary size of a beef brood herd that could absorb all the wastes from a feedlot can be estimated from the fact that 52 pounds of wastelage is produced per steer-day and in the feeding trials beef cows consumed on the average 21.6 pounds of wastelage per cow-day. The 2.4 cows per steer that would be required is probably a reasonable ratio to permit this regime to be universally applied (of 114,000,000 head of cattle on January 1, 1971, 12,000,000 were on feed for slaughter). However, it should not be anticipated that feedlot wastes will be transported and sold to separate farms since transportation costs would probably be greater than the benefit of making wastelage from feedlot manure as opposed to collected brood herd manure. If it becomes economically attractive to bring breed herds into confinement in the neighborhood of feedlots to absorb feedlot wastes, then the local manure disposal burden will in fact be increased by a factor of 2.4.

Cattle manure is not desirable as a poultry feed since for this market it would have to be dried, and the undigested fibers in cattle manure are better suited for ruminant digestion. A poultry feed market, if developed, would saturate before 1.3 percent of the available cattle manure would be utilized if the manure was fed as 10 percent of a poultry diet.

Where the fibers in ruminant manures are valued as an energy source, their digestibility can be increased by chemical treatment before refeeding. Smith, Goering and Gorden[110] found that treatment of orchardgrass and alfalfa cow feces with 3 percent sodium peroxide increased the nitrogen, cellulose and hemicellulose digestibility. Similar chemical treatments that can be performed without sophisticated equipment may prove worthwhile in refeeding schemes.

Feed use of sheep manure is not being considered at present except inasmuch as cattle manure is a representative ruminant manure and thus similar to sheep manure. The residue from oxidation ditches that accept swine wastes have a potential as animal feed,[111] but whole swine feces are not being considered as feed supplements. Distribution and marketing of manures as feedstuffs may be difficult or impossible, so reuse of manures on the premises of their generators is likely to be the most successful management technique. Refeeding schemes may be applied to any scale of cattle operation, but may be limited to larger poultry operations because of the high capital cost of drying equipment. Refeeding manure can benefit the environment by providing an incentive for immediate and careful manure collection, but can be a hazard if the biochemistry of trace compounds and feed additives is not appreciated.

Past and current research has indicated the gross nutritional feasibility of refeeding manure. Future research should emphasize investigation of health hazards and the economics of practical implementation. In determining the true economic benefits of refeeding, actual demonstration trials must be conducted. Perhaps the most economical farms of the future will return to the husbandry of a variety of animals so that feed materials can be efficiently utilized by convenient cross-refeeding between various kinds of livestock.

From the viewpoint of general solid waste management, however, refeeding methods may be of limited value because either the wastes are not completely consumed (as would be the case with cattle wastes) or the method is applicable only to a relatively minor waste (as would be the case with poultry manure utilization schemes).

ii. Fish Cultivation

Livestock manures have been utilized in the cultivation of fish at least since Roman times. Agrarian writers Pliny and Varro prescribed rules for the application of stable sweepings to fresh water fish ponds.[112]

However, today in the United States inorganic fertilizers are more commonly used. Occasionally it is suggested that a return to widespread use of manures in fish cultivation may help alleviate the agricultural solid waste burden while leading to the production of valuable, high-protein food.

Unfortunately, it does not appear that any fish can utilize manure solids as a major part of their diet. Controlled experiments with bullhead catfish, carp and pangasius (a Cambodian lungfish) have indicated that these fish starve to death when given only manure to eat.[113] Manure applied to a fish pond apparently encourages fish growth more indirectly than through direct feeding of the fish. Bottom feeding fish that are sometimes described as manure feeders, like the mud carp, Cirrhina Molitorella, in fact consume only the saprophytic organisms associated with manure on the pond bottom.[114] Other fish feed on the photosynthetic food chain that starts with simple algae which are fertilized by the nutrients released by the decomposing manures.

The advantage to a fish pond of applying manures, beyond the advantages of fertilization, is the increase in energy available in the saprophytic food chain. However, the saprophytic organisms can strip a still pond of the oxygen necessary for the survival of fish unless the green plants become comparably more prolific. Thus the application rate of the manure must be limited to avoid upsetting a delicate balance in pond life. Experimental studies have indicated that more than 10 to 15 tons of manure applied to an acre of still pond in a year leads to oxygen starvation.[115] Mechanical aeration seems to permit increasing this rate to only 20 to 30 tons per acre-year (estimated from the fact that mechanical aeration permits concentration of pond life to the point that fish yields are doubled[116]), indicating that the increased concentration of pond life leads to factors other than oxygen depletion that discourage fish growth, perhaps, for example, the concentration of toxins excreted by the fish themselves.

The high rate of application mentioned above, 20 to 30 tons of manure per acre-year, is too small to absorb the wastes generated by today's agriculture in manageably sized ponds. A mere two dairy cows each producing 60 pounds of manure per day would supply an acre of fish pond with a full load of 22 tons per year.

If a fish in demand as a human food, like the catfish, were cultivated, and yields typical of catfish production were obtained, one-half ton of fish per acre-year,[117] then the production from the ponds absorbing the waste from 72,000 head of cattle would saturate the 1966 U.S. demand for catfish of 18,000 tons (USDI figure).[118] Because catfish is a valuable crop, selling for about 35¢ per pound of whole fish, some livestock owners or food processors in the future will probably turn to catfish cultivation to assist in manure or effluent management. However, if fish ponds were to absorb any significant fraction of the nation's agricultural waste, the fish produced would have to be sold for processing as fish meal animal feed. Such feed would sell for 6¢ to 10¢ per pound, but the whole fish would be sold to processors for only 1¢ to 5¢ per pound. It is unlikely that a farmer would apply 15 tons of manure to an acre of fish pond that returns $50 (1000 pounds of fish at 5¢ a pound) instead of to an acre of corn field that returns $70 (70 bushels of corn at $1 a bushel).

Durham[119] has experimented with feeding pellets made from a mix of feedlot manure, cottonseed meal and sorghum to catfish. Fish fed such a ration survive, but apparently not all, if any, of the manure is consumed as the fish ponds tend to suffer from oxygen depletion after a period of time. The fish received 3.5 percent of their body weight daily in manure. Thus an acre of pond yielding 4000 pounds of fish per year could not be expected to absorb more than 0.035 × 4000 × 365 pounds = 51,000 pounds or 25.5 tons of manure. This is comparable to the rates found unsuitable for waste management above.

In summary, although we anticipate that fish ponds will be established in a few locations to absorb manure, and fish will be stocked in ponds that occasionally absorb diverse wastes from processing industries, fish cultivation cannot be expected to absorb a significant fraction of agricultural waste. This scheme of waste management is impractical because: (1) The space requirements are too great. (2) If widely applied, the scheme would probably be less economical than spreading wastes on cropland.

iii. Feeding Garbage to Swine

Feeding edible garbage to swine is a well-known and practiced method for extracting a resource value from a waste. However, the contribution of such a strategy to overall combustible solid waste management can only be very small. The separate collection by a city of residential garbage is a practice that will probably continue to disappear as more home garbage grinders are installed; modern packaging and refrigeration leads to less food waste; and modern refuse disposal techniques, such as incineration or sanitary landfill, are adopted to accept combined garbage and refuse. Furthermore, residential garbage is the least desired source of hog feed since it invariably contains uncontrollable amounts of inedible materials such as wrapping paper, glass and razor blades.

Restaurant and institutional garbage (about 5 percent of the total combustible solid waste load in a metropolitan area) is a more favored source of hog feed because large quantities can be collected at a relatively small number of locations. However, there remains a problem with the usual appearance of inedible paper, china, light bulbs, silver, cigarette butts, etc. Supermarket garbage may contain less inedible material, but this predominantly fruit and vegetable feed does not provide a balanced diet and must be mixed with other feeds. Garbage from military mess halls has been found to be the most desirable waste for swine feeding.[120]

Because of the threat of diseases, particularly vesicular xanthema and cholera, among garbage-fed swine, and the danger to humans of contracting trichinosis, state laws now require that all garbage fed to hogs be thoroughly cooked on the farm. In spite of this precaution, there remains considerable opposition, for example, from the National Pork Producers Council,[121] to feeding garbage to swine under any circumstances because it is felt that it is impossible to assure by occasional governmental inspection that proper sterilization of the garbage is taking place and because it is believed that feeding garbage to even only a few swine adversely affects the market price of all pork. These concerns have caused several states to completely outlaw feeding garbage to swine, and some other states appear likely to follow suit.

The major cost of this waste utilization strategy is the cost of collection, which in the future will have to be borne entirely by the farmer or a private contractor. Once on the farm, garbage is cooked in vats by direct fire or by wet steam injection in vats or specially designed collection trucks. The costs associated with cooking are $1 to $2 per ton of garbage.[122] An average ton of commercial garbage can produce 100 pounds of pork, providing a return of $20 per ton of garbage. Not all of the wastes are utilized, however, as only 40 to 60 percent of the collected garbage will be consumed by the swine, and the remaining wastes pose a disposal problem to the farmer. The most commonly applied solution is landfilling on the farm. The overall economics are apparently favorable, as evidenced by the fact that military installations in New Jersey can sell their garbage "at the back door" to hog farmers.

Since the contribution of swine feeding to solid waste management in the United States will remain very small at best, and since the practice is the state-of-the-art and needs no public assistance to be implemented, it need not be considered further in comprehensive strategy selection.

iv. Feeding Municipal Solid Waste to Cattle

The market for the cellulose fibers in composted refuse as a roughage feed was considered in section 3a on composting. At present, such a feeding scheme is only highly speculative and it must be anticipated that gaining FDA approval and public acceptance would be practically impossible because of the lack of control that can possibly exist over the constituents of municipal refuse.

e. Cultivation of Insects on Wastes

Essentially all methods of biological conversion of combustible waste involve the utilization of a waste material as a food for an organism, be it a yeast cell or a cow. The organisms that are capable of making the most efficient conversion of waste into useful products are microorganisms because of their rapid growth (doubling times of a few hours). However, this efficiency may come at too high a price if the microorganisms require a carefully controlled environment. In this case, it may be more economical to utilize a larger organism that is well adapted to the environment in which the waste material occurs. Some insects may be attractive in this context because they also have fairly short generation times, on the order of days; commonly feed on wastes; and can be a palatable feed for domestic livestock, particularly poultry.

Currently only one particular application of an insect to a waste material is being studied in an attempt to develop a waste management scheme. This is the processing of poultry manure by housefly larvae. Since this process evidently has such a specialized application it was not fully evaluated, but is discussed here at some length in order to point out some of the considerations that would be generally involved in processing wastes with insects.

The use of the housefly in the management of poultry manure is being considered by Calvert[123,124,125] at the U.S. Department of Agriculture research station at Beltsville, Maryland, and by Miller[126] at Colorado State University. Miller screened five species of flies as potential means of converting poultry manure into high-quality protein, but selected Musca domestica, the housefly, "because it reproduced in large numbers and required a minimum of time (five to ten days) to reach pupal stage." It is found that the developing housefly larvae actually consume only an insignificant fraction of the manure. However, they process the manure by aerating it with their tunnels, which leads to a composting-like degradation of the manure, and they consume some moisture and readily available organic compounds. The results of the processing are fly pupae that can be ground as chick feed, and dry (30 percent moisture), crumbly humus free of obnoxious odors.

TABLE 73

ANALYSIS OF DRIED GROUND FLY PUPAE

Proximate Composition[a]		Amino Acids		Fatty Acids	
Constituent	%	Constituent	% Protein	Constituent	% Total
Protein	63.1[b]	Arginine	4.2	Lauric	0.6
Fat	15.5	Clycine	3.9	Myristic	3.2
Moisture	3.9	Histidine	2.6	Palmitic	27.6
Ash	5.3	Isoleucine	3.5	Palmitoleic	20.6
Other	12.2[c]	Leucine	5.3	Stearic	2.2
		Lysine	5.2	Oleic	18.3
		Methionine	2.6	Linoleic	14.9
		Phenylalanine	4.2	Linolenic	2.1
		Threonine	3.4	Unidentified	10.5
		Valine	3.4		
		Glutamic Acid	10.8		
		Alanine	4.2		
		Cystine	0.4		
		Tyrosine	4.9		
		Proline	3.1		
		Serine	3.2		
		Aspartic	8.5		
		Ammonia	2.1		

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[a] Determined by the Official Methods of the Association of Official Agricultural Chemists, 9th Ed., 1960, Washington, D.C.

[b] Nitrogen x 6.25.

[c] Primarily nitrogen-free extract and fiber.

From the experimental results we can visualize how a manure management scheme based on the housefly would be applied to a laying operation of 8,000 hens producing one ton of wet (75 percent moisture) manure per day. A breeding stock of flies is maintained in a screen cage no larger than a couple cubic meters that is kept at room temperature. At regular intervals the manure is collected, by dry-handling techniques, from trays underneath the cages in the hen house and brought to the processing shed. This building is part of the hen house or is immediately adjacent and is maintained at temperatures of 68 to 80 degrees F and supplied with continuous overhead lighting. The building contains 60 square feet of hardware cloth-bottomed trays for each ton of manure expected in a week, or 7 x 60 = 420 square feet for our hypothetical farm. To permit access aisles between the trays, the floor space of the processing shed would total 1,000 square feet. The poultry feces are brought from the hen house by wheelbarrow and dumped into the top portions of the trays. (To facilitate this, alternate access aisles in the shed should be catwalks raised above the level of the trays.) The feces are spread evenly to a depth of 2-1/2 to 3 inches. Housefly eggs are then collected from the breeding stock by placing into the screen cage a sponge saturated with a dilute ammonia solution on which the flies will lay eggs. The fresh eggs are seeded onto the feces at a rate of three eggs per gram of feces. During the next seven days the eggs hatch, the larvae develop and aerate the medium by their tunneling. The continuous overhead light prevents the negatively photactic fly larvae from wandering upward in search of a pupation site, and by the end of the week most of the larvae have passed through the 1/8-inch hardware cloth floor to a lower screen tray--some particles of the larvae medium also drop through the hardware cloth to the screen tray. This lower screen is sufficiently flexible to allow the vermiform larvae to wiggle through and drop to the solid floor to pupate, but very little medium passes through the screen.

The pupae are collected, dried and ground to prepare them as a feed supplement. The feed will contain 63.1 percent protein and 15.5 percent fats (Table 73). Between 40 and 80 pounds of the feed is produced per day and can be used as a replacement for soybean meal. Soybean meal with 50 percent protein content sells for 6¢ to 7¢ per pound, so the pupae meal should be worth about 8¢ a pound. Thus the poultry farmer has produced a resource that has a value to him of $3.20 to $6.40 per ton of wet manure.

The processed manure has been reduced in weight by 50 percent, most of this being a loss in moisture from 75 percent to 30 percent. Before this residue can be disposed of on land, any fly pupae it might contain must be destroyed. This could be done by feeding the residue through a furnace that will heat it momentarily to 130 degrees F. The cost experience of a sample of poultry house operators interviewed by Cornell University researchers provides figures representative of the waste management costs of the modern large-scale poultry farm for manure disposal.[127] Total annual costs for hauling manure one-half to one mile to fields and spreading, including labor, power and equipment with charges for depreciation, interest and other overhead, amounted to 80¢ per ton of manure (1966). If the same costs apply to disposal of the residue, which has half the weight of the manure, the cost of residue disposal in terms of the input manure is 40¢ per ton of wet manure.

It is readily apparent that cost of the labor alone (at least four hours per ton of manure) described above will be greater than the \$3.20 to \$6.40 potential return on protein feed and the \$0.40 saving on disposal. Thus this management scheme will only be applied where it is expected that the residue also has value as a specialty soil conditioner, or an animal feed. For these potential markets the manure residue must be dried to 10 percent moisture. Currently the cost of thermal drying of manure from 75 percent moisture to 10 percent is \$6 per ton of wet manure when fossil fuel heat is used. From this we can estimate the cost of thermal drying from 75 percent to 30 percent to be \$2.28 per ton. It is with this latter figure that the cost of processing with houseflies must compete. That is, the cost of processing and capital equipment must be less than \$2.28 per ton of manure, plus the conservative value for the protein resource, \$3.20 per ton of manure, a total of \$5.28 per ton of manure.

It has been recognized by Calvert and Morgan at Beltsville that these costs, \$5.28 per ton of manure, cannot be approached if the laboratory system is scaled up as described above. Accordingly, they have been investigating completely different management techniques based on the principle of fly cultivation, but employing greater mechanization to reduce labor costs. Presently the most promising-looking technique involves cultivation of larvae in manure agitated in a rotating drum. Until a particular mechanical process is determined as feasible, it won't be possible to make a clear cost estimate. The concept of digestion in a rotating drum is very reminiscent of the digestion phase of mechanical composting which can be performed for costs comparable to \$5 per ton. However, the establishment of a complex two-step process involving both digestion and sophisticated drying techniques may be more than most poultry farmers would want to get involved in, especially if the economic advantages were marginal. Furthermore, heat-drying in a single step results in a product with 35 percent more nitrogen than the residue left after the high-protein pupae are removed from digested manure (2.7 percent as opposed to 2.0 percent). This will reduce the value of the product as a fertilizer and feed supplement.

In practice, besides the economic problems, the public health issues must be considered. Miller claims there is a benefit in the cultivation of flies in that the breeding sites for wild, disease-carrying flies are eliminated. However, this is true of all sanitary manure management and is not peculiar to this particular management scheme. Furthermore, complete control may prove to be rather tricky since conventional insecticides could not be used around the hen house as they might discourage the larvae growth. Another problem that is common to all schemes that involve feeding of waste-grown organisms is the recycling and possible concentration in tissues of contaminants. With larvae grown on poultry manure, these might include arsenicals fed as growth stimulants and antibiotics. Preliminary studies by Calvert indicate that the arsenicals are not concentrated in the larvae. But the full range of potentially harmful chemicals must be investigated.

Let us summarize the state of development of manure management by cultivation of insects. Of the various insects that breed in manure, only the housefly has so far been selected for study. Cultivation of fly pupae returns $3.20 to $6.40 per ton of wet poultry manure from the fly protein feed produced. The production cost, however, with present technology is greater than this return. Automated technologies being developed may be expected to operate at costs comparable to this return, but will probably not be profitable unless the manure residue is more completely dried and sold as soil conditioner or feed. Such a complex operation involving both biological conversion and heat-drying would probably be undertaken only on a very large scale, perhaps by a processing plant central to several poultry farmers.

Waste management schemes based on other insects have not been reported. However, some ideas are being considered. For example, crop residues are sometimes considered undesirable because they harbor plant pathogens. If these residues were collected and pathogenic insects permitted to multiply, they might be harvested as a protein source. Another suggestion for manure management is to use manure as a culture medium for insects that are predators of plant pathogens. This could provide another incentive for spreading manure on cropland. Evaluation of the technical and economic feasibility of such schemes awaits the suggestion of candidate organisms.

4. Mechanical Processes

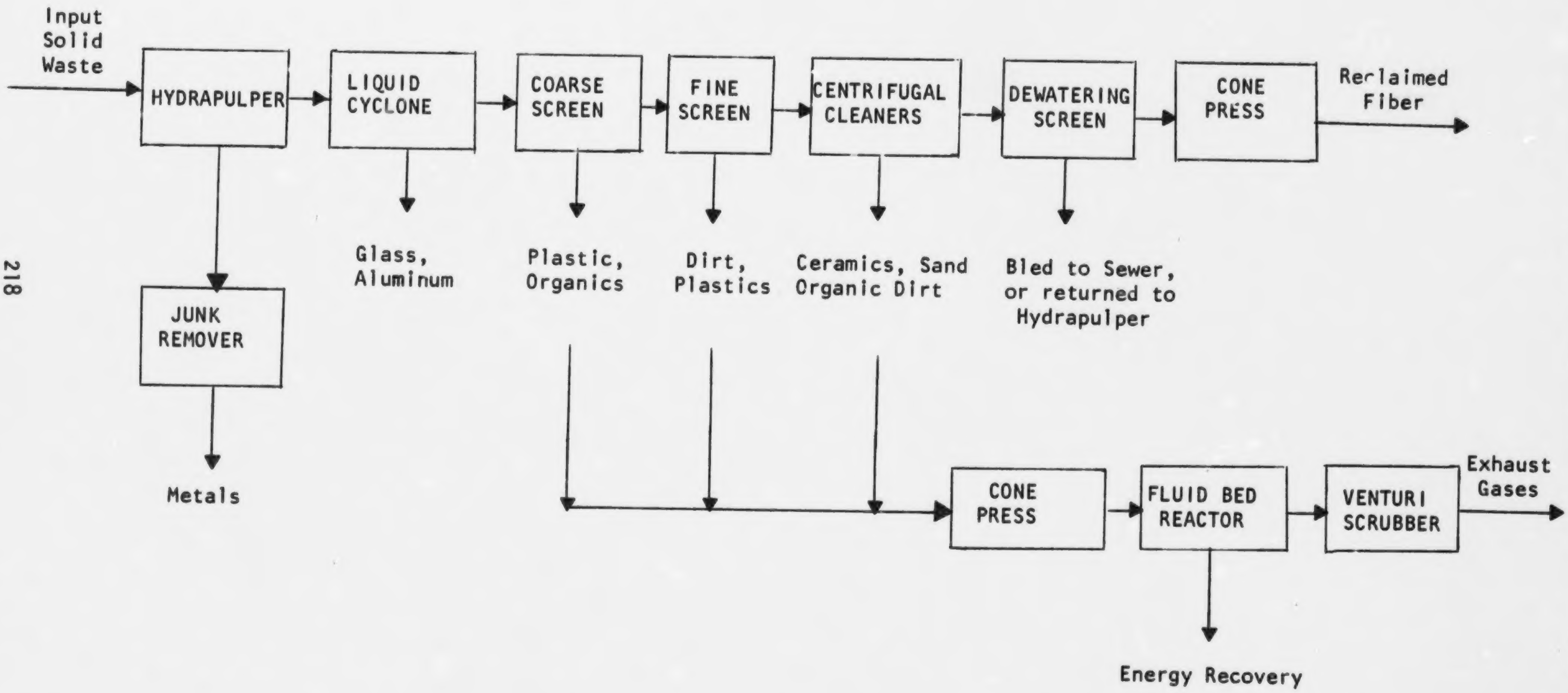
a. Wet Fiber Recovery

i. Process Description

Wet fiber recovery involves a system to recover paper fiber from mixed municipal solid wastes by means of selective screening of shredded wastes.[128] In this system incoming refuse is dumped into a storage hopper or discharged onto an apron conveyor from

FIGURE 24

FLOW DIAGRAM FOR A WET FIBER RECOVERY PLANT



which it is fed continuously into a wet pulper. In the pulper, a rotor reduces all pulpable, grindable, and friable materials, such as food wastes, paper, plastic, rubber, rags, glass, wood, leaves, etc., to sufficient size to pass through 1/2-inch holes in an extraction plate located beneath the rotor. The heavy inorganic materials are rejected by the pulper and removed by a bucket elevator. The pulped material, in the form of a water slurry, is pumped to a liquid cyclone to separate heavy materials, such as dirt, sand, broken glass, small pieces of metal, bone, etc. The remaining organic material passes through a series of screens, one of which separates and rejects coarse organic material composed of rags, plastic, food waste, etc.; another removes fine dirt (plastics, vegetation, etc.). The remaining water slurry then passes through centrifugal cleaners which remove any fine particles of heavy dirt (glass, ceramics, sand) which may have passed the liquid cyclone. The centrifugal cleaners also free the remaining stock from particles or organic dirt (coffee grounds, leaves, grass, etc.). The paper fiber is progressively concentrated. The remaining slurry is now passed through a fiber selector which selectively removes most of the long chemical fiber. The selector is basically a hydrasieve thickener which increases the proportion of long fibers in the remaining water slurry by removing fine particles and shorter fibers through a screen. The long fibers are then dewatered and baled. The rejects from the selector are passed through a secondary selector which removes intermediate-length fibers, which are also dewatered and baled.

The rejects from the screens, centrifugal cleaner, and secondary selector are sent to a waste treatment plant. Clarified water is recycled for use in this system. The slurry is dewatered by dewatering screws and press, and oxidized in a fluid bed reactor. Exhaust gases are cleaned by wet scrubbers. Ash from the scrubbers is dewatered and combined with the washed rejects from the liquid cyclone and junk remover. This inert residue is then landfilled.

Virtually all the equipment used in this system has been in use in other capacities for some time. The one wet fiber recovery system in operation will soon be adding a sorter to separate aluminum and color-sorted glass. A flow diagram for a wet fiber recovery plant is shown in Figure 24.

A breakdown of wet fiber recovery costs is shown in Table 74.

The capital cost of a 400-ton-per-day system for wet fiber recovery is $4,600,000, which amortizes to $3.00 per ton. The operating cost is $1.70 per ton, and the total cost $4.70 per ton.

A materials balance chart indicating input (mixed municipal solid wastes) and output in a wet fiber recovery system shows that for 100 pounds of input waste, 18 pounds of paper, 6 pounds of iron, 4 pounds of glass, and 0-5 pounds of aluminum can be recovered,

TABLE 74

COSTS OF WET FIBER RECOVERY PROCESS

1. Capital cost:	
For a 224-tons/8-hr-shift plant Or $11,000 per ton/day capacity	$2,247,184
2. Operating cost (excluding taxes):	
For a 224-tons/8-hr-shift plant:	
a) Labor:	
1 Area operator 40 hr/week at $6.15/hr	12,792
3 Area helper 40 hr/week at $4.70/hr	29,328
b) Maintenance (1.75% of capital)	152,190
c) Power:	
2200 hp x .746 kw/hp x 520 hr x $0.013/kwh	44,586
d) Water:	
$0.017/100 gpm x 200 gpm x 60 m/hr x 520 hr	3,183
e) Operating supplies (.1% of capital)	8,697
f) Insurance ($0.15/$100 of capital)	4,348
	$ 255,124
3. Depreciation: 15 yrs at 6% = $224,718/yr	
4. Cost per ton:	
$\frac{224{,}718+255{,}124}{672\times 260} = \frac{479{,}842}{174{,}000} \quad \$2.75/\text{ton}$	
5. Incoming revenue from possible sale of:	
Paper (18 lb paper/100 lb refuse, or 40 tons paper/224 tons refuse) at $8-20/ton of paper	$ 320-800
Ferrous metal (6 lb iron/100 lb refuse, or 13 tons iron/224 tons refuse) at $4-20/ton of iron	42- 80
	$ 362-880
Or, a total revenue of $1.62 - $3.93/ton of refuse	

Source: Municipal refuse recycling plant. Rust Engineering Co., 1970.

along with energy recovery if desired.[129] The only output materials being removed for sale at present are the paper stock and ferrous metals. It is expected that glass and aluminum will also be sold in the future when sorting equipment for this purpose is installed.[130]

1 Ton Solid Waste	Resources
500 lb water	500 lb water
200 lb metals	630 lb combustible matter (energy source)
160 lb glass	300 lb landfill materials
800 lb paper	10 lb aluminum
340 lb miscellaneous goods (plastic, textiles, yard wastes)	120 lb iron
	80 lb glass
	360 lb paper

ii. Marketing

In 1970, 52,600 million tons of paper and paperboard products were produced in the United States. Approximately 12 percent of this amount was utilized in permanent forms, e.g., as books or building materials, or was disposed of by home burning or sewer systems; approximately 20 percent was reclaimed and reused; the remaining 68 percent became solid waste. Two recent sets of projections have been made of the future market for fiber recovered from paper and paperboard. One, by the U.S. Department of Agriculture Forestry Service, assumed that historical trends away from paper fiber reclamation and toward use of virgin wood pulp would continue. The other, by the American Paper Institute, assumes that the increased pressure for recycling will reverse the historic trend. The projections are presented in Table 75.

TABLE 75

PROJECTED PRODUCTION OF PAPER AND PAPERBOARD AND WASTE PAPER CONSUMPTION (000 TONS)

Year	Production[a]	Waste Paper Consumption	
		A.P.I.	U.S.D.A.[b]
1970	52,600	12,000	12,000
1980	81,000	19,520	14,900
1990	118,000	39,000	20,060[c]

[a] American Paper Institute, September 1971.
[b] U.S.D.A., Forest Service, Forest Resources Report No. 18.
[c] Extrapolated by ECASSO.

The wet fiber recovery process currently recovers approximately 45 percent of the paper fiber in the waste streams being processed, or 18 percent of the total waste throughput. Applied to the total projected waste throughput from urban areas for 1990, the wet fiber recovery rate would yield 41.67 million tons of fiber from municipal solid waste against the API projected waste paper demand for 39 million tons in a year in which the paper industry would also generate 28.95 million tons of paper waste.

Prices for waste paper fluctuate abruptly. In January 1968, prices were 76.9 percent of their 1957-1959 average; a year later they were at 107.4 percent. As of December 1971, mills were offering $21.00 per ton for No. 1 news, a relatively inexpensive grade. The wet fiber recovery process has based its income projections on $25.00 per ton for recovered fiber; a brief industry survey yielded several estimates of $15.00 per ton for the fiber.

iii. Evaluation

Net Costs. A total credit of $6.00 may be taken for resources recovered in this process: paper fibers, $2.75 per ton; iron, $1.30 per ton; aluminum, $1.25 per ton; glass, $0.70 per ton.

A marketing and distribution cost of $1.50 may be expected, bringing the net cost of this process to $4.70 - $6.00 + $1.50 = $0.20.

Rating: 8/8.

Waste Reduction. Besides the great reduction in noncombustibles encountered, the wet fiber recovery process extracts 52×10^6 tons per year of waste fibers. This leaves the remaining portion of wastes (mostly combustible) as an excellent energy source through combustion, which leaves a negligible residue.

Rating: 8/8.

Flexibility. The system has to be able to locate steady markets for the secondary materials it is recovering. Fluctuating markets and prices for these products in various geographical locations may reduce the locational flexibility of this system.

The paper fiber extracted from municipal wastes by this process is contaminated to some extent by rapidly decaying organic matter (plants, foods, etc.) and hence may be subject to deterioration over some period of time. This would limit the storability and usability of these fibers.

Changes in waste stream composition would affect the economics of this system, although not the technology (except in the scale size of various pieces of equipment).

If energy is to be recovered then the plant must be situated relatively close to customers for this energy.

However, considering future trends in solid waste generation and composition, such a system appears to meet the needs of resource recovery.

Rating: 4/8.

State of Development. This system is currently in full-scale operation on a 50-tons-per-8-hour-shift basis in Franklin, Ohio. The system is being studied for problems and refinements.

Rating: 4/8.

Conservation of Natural Resources. This process recovers a large number of resources. However, the combustible portion recovered (paper fiber) is a renewable resource (as compared to fossil fuels which are nonrenewable).

Rating: 4/8.

Weighted Total:

8x33 + 8x28 + 4x12 + 4x19 + 4x8 = 644/800.

b. Dry Fiber Recovery

i. Process Description

This process is still in the experimental, bench-model stage. Mixed municipal solid wastes are first reduced in size by processing through a shredder. The wood fiber portion of the solid wastes can then be separated out using a dry screen and air classifier.[131]

Screening is a technique for separating materials based upon particle size and involves the separation of a mixture of various size particles into a number of fractions, each of which is more uniform in particle size than is the original mixture.

Another device similar to conventional dry screens that has been used in the separation of solid wastes is the stoner.[132] A stoner is basically a dry vibrating table that operates by passing a stream of air upward through an inclined screen or perforated table. Feed enters near the top of the inclined screen. Lighter particles are buoyed up by the air passing through the screen and flow downward to the lower end where they are discharged. The inclined screen vibrates in an oscillating motion which causes the dense particles to migrate upward along the screen surface and discharge over the higher end of the table. By proper installation of baffles and selection of the point where feed material enters, a feed stream containing materials with different specific gravities can be separated into several product streams. In order to effect good separation, particle size must be controlled rather closely. Otherwise, large, less dense particles may end up in the heavy fraction and small heavy particles may end up in the light fraction. Size control is normally accomplished by screening.

Air classification, the process used subsequent to dry screening, has not yet achieved any major application in solid waste processing. A number of efforts are presently being made in this direction, however, including development of a zig-zag air classification unit and evaluation of horizontal and vertical elutriators.[133]

Air classifiers work on the principle that, by exhausting air through them, the law of inertia and Stoke's Law on terminal velocity are utilized to separate materials of different specific gravities and sizes. A suitable feed preparation is required prior to air classification. This usually includes shredding, and quite often drying and screening, to achieve optimum separation of materials.

Of particular interest are findings that indicate special care must be taken in the selection of shredders used prior to air classification. Size reduction equipment that reduces particle size, but produces detrimental aerodynamic characteristics and an undesirable agglomeration of the components of refuse, will reduce the efficiency of subsequent air classification.

Further research indicates that particular size reduction techniques may enable subsequent air classification to separate waste papers according to grades. This would be particularly beneficial in that higher grade papers could be reclaimed for uses which are now completely dominated by virgin materials.

Two experimenters have recommended a series of three classifiers for waste paper recovery from mixed municipal refuse. Experiments with the zig-zag air classifier have resulted in the definition of specific fluidizing velocities to separate out components of the waste mixture. The suggested apparatus consists of three pairs of centrifugal separators arranged in series, six large-diameter mechanical cyclones, and six exhaust fans, so that a cyclone and an exhauster are connected to each separator. Shredded material is fed at a constant rate through rotary valves into the top of the two primary separators. The plastics and food will tend to remain in the center of the rotating separators and are exhausted out the tops through cyclones that separate this material from the exhaust air. The heavier materials in the primary separators migrate to the walls and fall by gravity through rotary valves to the tertiary separators which separate out the glass component.

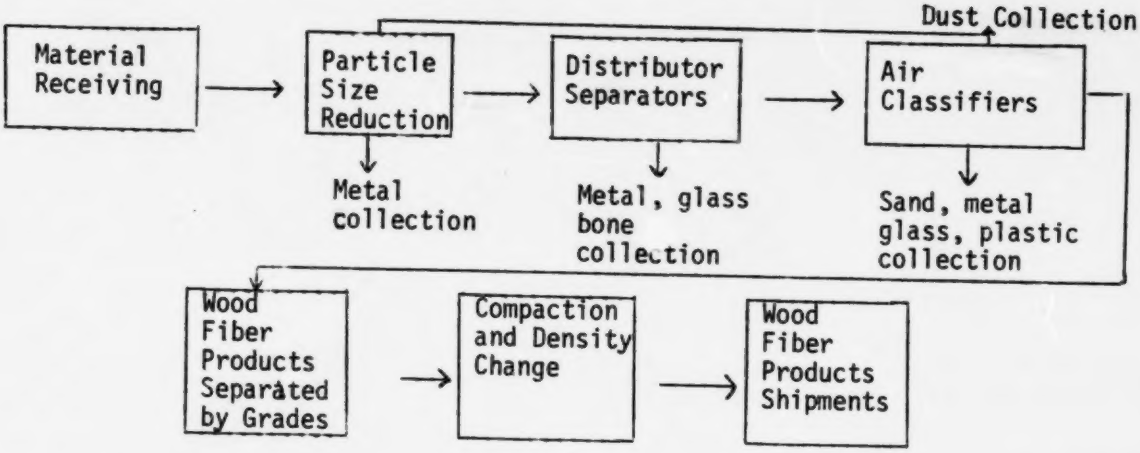
In the dry fiber reclamation process, shredding followed by air classification forms the first step in waste paper recovery.[134] The paper fraction from air classification of the shredded raw refuse will be pneumatically conveyed to a separator storage bin located above the dryer feed inlet. Mixed papers will pass from the storage bin through a rotary feeder to the gas-fired dryer inlet. Paper products at 10 percent moisture and approximately 130 degrees F will be pneumatically discharged from the flash dryer through a material handling fan to a discharge cyclone. Mixed papers from the dryer discharge cyclone will be metered to a feed screw feeding a double rotating disc refiner which is a size reduction device with high-speed contrarotating discs between which selected material is passed and torn to bits, with fibers remaining intact. The refiner will be pressurized with 150 psi saturated steam at the rate of about 1 pound of steam per pound of oven dry fiber. A discharge conveyor from the refiner will feed a fiber classifier. The mixed refined fibers will be classified by length and conveyed from the classifier to storage bins located above the baling presser. Classified fibers, long and short, will be metered to the hydraulic balers and 50-cubic-foot bales will be strapped and conveyed to storage. Each bale will weigh approximately 1500 pounds and will be handled by lift truck from strapper to storage and to shipment. Wood fibers will bypass the classifier and go directly to the balers.

A flow diagram for a dry fiber recovery plant[135] is presented in Figure 25.

Assuming a 5-day-per-week, 8-hours-per-day operation over 52 weeks or 2080 hours, at an input of 22.5 oven dry tons of shredded mixed municipal wastes per hour, the costs of the dry fiber process are \$2.70 per ton of input refuse, or \$5.40 per ton of output product (paper fiber).

The costs of screening are related almost entirely to equipment costs and only in a small way to operating costs which are dictated principally by power consumption. Capital costs of screens depend upon the size of openings in the screen, the rate of loading on the screen, the nature of the material to be screened, and how many decks of screens are to be used. Paper can most probably be effectively separated from mixed municipal solid wastes by using a double-deck screen with openings of +3/4 inch. A screen that can separate paper from mixed municipal solid wastes (which have a

FIGURE 25
SYSTEM FOR REMOVING WOOD FIBER PRODUCTS FROM MUNICIPAL SOLID WASTE


Material Receiving
Particle Size Reduction
Distributor Separators
Air Classifiers
Dust Collection
Metal collection
Metal, glass bone collection
Sand, metal glass, plastic collection
Wood Fiber Products Separated by Grades
Compaction and Density Change
Wood Fiber Products Shipments

From: Carr, W.F. Value recovery from wood fiber refuse. In Proceedings of the Second Mineral Waste Utilization Symposium, March 18-19, 1970.

density in the order of 10 pounds per cubic foot) should have a loading capacity of one to two tons per hour per square foot of screen. Thus, a double-deck vibrating screen able to process 50 tons per 8-hour shift would cost between $3,000 to $5,000, which is very inexpensive (under 2 percent) compared to the cost of a shredder, building, and other facilities needed for either a wet or dry screening process.

Stoners have been used in two compost plants to separate out glass and nonmetallics. Capital costs range from $2,000 to $10,000. For a 50-ton-per-8-hour-shift operation, a stoner would cost $10,000. It would probably need to be used in conjunction with a vibrating screen. These costs are still, however, considerably less than the wet separation process would seem to entail. Operational costs on the stoner are dependent on power requirements which are very low--on the order of 1 hp (0.75 kw) per ton per hour.

Detailed costs for the dry fiber recovery process in a 180 ton per day plant are shown in Table 76.

The capital cost of a 400-ton-per-day system is $1,650,000, which amortizes to $1.17 per ton. Operating costs average $5.16 per ton, and total costs $6.33 per ton.

Materials Balance

1 ton input municipal solid wastes (25% moisture content)	800 lb paper fiber 140 lb iron 140 lb glass 500 lb water 420 lb landfill or energy production

ii. Marketing

The market for fibers extracted by this process will be similar to that for fibers recovered in the wet extraction process discussed above (4a).

iii. Evaluation

Net Costs. A total credit of between $7.53 and $10.03 per ton may be taken for resources recovered: paper fiber, $5.50 to $8.00; iron, $1.33; glass, $0.70. A marketing and distribution cost of $1.81 to $2.51 is expected. This net cost = $6.33 - ($7.53 to $10.03) + ($1.81 to $2.51) = a cost of $0.68 to a profit of $1.19.

Rating: 8/8.

TABLE 76

COSTS OF DRY FIBER RECOVERY PROCESS

Dry Fiber Process	Cost	% of Time	Assessed Cost
Labor			
1 area operator (same as wet fiber)			
1 area helper (same as wet fiber)			
Total	$ 22,568	100	$ 22,568
Maintenance (3-1/2% of capital)	33,244	50	16,622
Power (1947 hp connected; 1160 kW average demand; 2,417,800 kWh/yr x 0.13/kWh)	31,366	25	7,842
Gas (8×10^6 BTU/hr x 2080 hr x \$0.52/10^6 BTU)	8,642	25	2,163
Steam (20,000 lb/hr x 2080 hr x $0.50/1,000 lb)	20,800	25	5,200
Operating Supplies (.1% of capital)	1,000	100	1,000
Insurance ($.15/$100 capital)	1,424	100	1,424
Taxes	6,432	100	6,432
Depreciation	63,322	100	63,322
Total	$188,808		$126,573

Source: Municipal refuse recycling plant. Rust Engineering Co., September, 1970.

Waste Reduction. Besides removing a substantial portion of noncombustibles, the usable paper fiber extracted by this process ($103x10^6$ tons per year) is double the quantity extracted by the wet fiber process ($52x10^6$ tons per year). This is because much of the wet pulp in the wet fiber recovery process becomes unusable after the wet grinding and successive screening operations involved. Such a destruction of fibers does not occur in the relatively simpler air classification used in the dry fiber recovery system.[136]

Rating: 8/8.

Flexibility. This is similar to the flexibility of the wet fiber recovery process.

Rating: 4/8.

State of Development. Some of the pieces of equipment involved are still in an experimental stage, although the entire system has been shown to be practical on a laboratory scale.

Rating: 4/8.

Conservation of Natural Resources. Although a substantial quantity of resources are recovered, the main combustible fraction (paper fibers) is a renewable resource (compared to nonrenewable fossil fuels).

Rating: 4/8.

Weighted Total:

8x33 + 8x28 + 4x12 + 4x19 + 4x8 = 644/800.

c. Drying of Sludges

i. Process Descriptions

Sludge is dried for two basic reasons: first, in preparation for some other process of sludge handling; secondly, in order that dried sludge may be sold or given away as soil conditioner. Sludge may be dried from 96 percent moisture content to 80 percent moisture content by either air-drying or mechanically dewatering. Drying by artificial heat can reduce moisture content from 80 percent to 10 percent.

Mechanical Dewatering. Common forms of mechanically dewatering sludge include vacuum filtration, pressure filtration, centrifugation, and screening. Of these, vacuum filters are the most popular, followed closely by centrifuges.

Vacuum filters separate solids from sludge by pressing the sludge through a porous medium on which the solids remain to form a cake. In a typical rotary drum vacuum filter, the filter is a cylindrical drum with some filter media covering the outside surface. The drum is divided on the inside into drainage compartments which connect to the filtrate system. About 20 to 40 percent of the drum is submerged in a filter "pan" containing the sludge. As the drum is rotated a sludge mat is formed on the filter media as a result of a vacuum (10 to 26 inches of mercury) applied to the drainage compartments servicing this submerged portion. As the mat, or cake, rotates out of submergence, vacuum and dewatering are continued. The cake is removed from the drum which is then submerged again.

Vacuum filters have been popular because a wide variety of sludges can be dewatered; filters occupy less space than lagoons or sand beds and are unaffected by climate; the filter cake can be directly incinerated, thus perhaps avoiding the need for digestion of sludge; filters allow flexibility in scheduling activities at a wastewater treatment plant; and the solids capture can be very good.

However, vacuum filters suffer from high operating costs, frequent media blinding, odors, a need for highly trained filter operators, and an inability to accommodate fluctuations in sludge quantity and quality.

Centrifuges are in many instances replacing vacuum filters. The most effective centrifuges appear to be horizontal, cylindrical-conical, solid bowl machines. This device separates solids from sludge by sedimentation and centrifugal force. In a typical unit, sludge is fed through the hub of the screw conveyor. The screw conveyor is mounted inside the rotating conical bowl. It rotates at a slightly lower speed than the bowl. Sludge leaves the end of the feed tube, is accelerated, passes through the ports in the conveyor shaft, and is distributed to the periphery of the bowl. Solids settle through the liquid pool, are compacted by centrifugal force against the walls of the bowl, and are conveyed by the screw conveyor to the drying or beach area of the bowl. The beach area is an inclined section of the bowl where further dewatering occurs before the solids are discharged. Separated liquid is discharged continuously over adjustable weirs at the opposite end of the bowl.

Advantages include: low costs; the unit is totally enclosed, minimizing odors; the unit is simple and small; little supervision is required; and flexibility in handling a range of solids.

Disadvantages include: the unit is not as effective in solids removal as vacuum filters; and trash must be removed from the centrifuge feed by screening.

Air Drying. Air drying on open or covered sand beds is the most common method of dewatering sewage sludge in the United States. Drying on sand beds occurs by drainage and evaporation, the rate depending on weather conditions, sludge characteristics, use of sludge conditioning aids, and subsoil permeability. With increasing land values and public disapproval of close-in drying beds, the economics of this method of dewatering sludge are highly questionable.

Drying beds usually consist of 4 to 9 inches of sand over 8 to 18 inches of graded gravel or stone. They are drained by underdrains spaced from 8 to 20 feet apart. Underdrain piping is usually vitrified clay laid with open joints, having a minimum diameter of 4 inches and a minimum slope of one percent. Collected filtrate is returned to the wastewater treatment plant. Sludge is well distributed over the drying bed because even 96 percent moisture content sludge will not travel more than 50 feet because of its relatively high viscosity, which increases as it dewaters.

Heat Drying. Sewage sludge intended for use as a soil conditioner is sometimes heat-dried to reduce moisture content to approximately 10 percent in order to reduce handling costs. However, unlike incineration in which auto-combustion is possible, heat drying requires the burning of significant quantities of oil, gas, or coal. In addition, control and maintenance of this process is more complicated than that for straight incineration. Air pollution and odor problems are also more severe than those for incineration. Heat drying, in an acceptable form, costs more than incineration. Unless high credits are obtained for the resulting sludge soil conditioner the process is economically unfeasible.

Heat drying usually requires preliminary dewatering of wet sludges (96 percent moisture content) to 80 percent moisture content by mechanical or air-drying processes. Heat-drying equipment includes one of the following types of dryers: flash, multiple hearth, rotary, or atomizing spray.

Multiple hearth dryers are similar to the multiple hearth incinerator described previously in this chapter. Modifications would include fuel burners at the top and bottom hearths plus downdrafting of gases. As the solids move downward through the furnace, the gases become cooler and the solids become drier.

The most common type of dryers being used at sewage treatment plants are flash dryers. In this process semi-dried sludge is

TABLE 77

HEAT-DRYING COSTS

	Incineration or Drying Equipment				Incineration Equipment	
	Incinerated Sludge		Dry Sludge		Incinerated Sludge	
	With Deodor.	Without Deodor.	With Deodor.	Without Deodor.	With Deodor.	Without Deodor.
Operating Cost	9.82	6.60	24.90	17.50	9.50	6.36
Capital Cost	12.12	11.59	12.52	11.59	9.47	9.15
Cost ($/Ton Dry Solids)	$21.94	$18.19	$37.42	$29.09	$18.97	$15.51
Vacuum Filtration Annual Cost	10.51	10.51	10.51	10.51	10.51	10.51
Total Sludge Handling Cost ($/Ton)	$32.45	$28.70	$47.93	$39.60	$29.48	$26.02

Source: Burd, R.S. A Study of Sludge Handling and Disposal, U.S. Department of the Interior, Water Pollution Control Research Series, Publication No. WP-20-4.

mixed violently with hot gases (1300 degrees F) in a cage mill, dried sludge being separated from the gases in a cyclone. A portion of the dried material is returned automatically to the mixer for use in conditioning incoming wet sludge. Combustion of fuel in the form of gas, oil, or coal provides the heat for the process. Vapors from the flash-drying process are returned through preheaters to the furnace where they are heated to 1200 degrees F to destroy odors.

The costs of mechanical dewatering average about $1 per ton of input sludge.

Drying beds have been popular because of low costs and simplicity. However, hidden costs such as land values, the need for digesting prior to air drying, and the cost of ultimately disposing of dried sludge leave sand bed drying no more economical than mechanical methods of dewatering.

Although heat drying has been in practice for some time, the economics of the system leave heat drying as the most expensive sludge handling technique in practice. Total costs are in the range of $2.00 per ton of input wet sludge (96 percent moisture content). A breakdown of these costs indicates the proportion of total costs shared by deodorization and initial dewatering (Table 77).

The economics of heat drying rest completely on credits obtainable for the resource recovered. Prices for dried sludge sold as soil conditioner tend to fluctuate in accordance with chemical content.

Materials Balance

1 ton input sewage sludge (96% moisture content: 80 lb solids, 1920 lb water)

→ Mechanical Dewatering: 320 lb sludge (75% moisture content: 80 lb solids, 240 lb water)

→ Air Drying: 160 lb sludge (50% moisture content: 80 lb solids, 80 lb water)

→ Heat Drying: 89 lb sludge (10% moisture content: 80 lb solids, 90 lb water)

ii. Evaluation

Net Costs. No credits are expected for mechanically dewatered or air-dried sludge. For heat drying, based on: 20¢ per lb - nitrogen (3 to 10 percent in undigested activated sludge); 10¢ per lb - phosphorus (1 to 3 percent in undigested activated sludge); 5¢ per lb - potash (0.1 to 0.3 percent in undigested activated sludge); activated sludge in the current market should be worth $20 per ton (dry solids), equivalent to $0.80 per ton (wet sludge), and primary sludge should be worth $11 per ton (dry solids).

On the basis of primary sludge to activated sludge being a 1:4 ratio, a ton of dry mixed sludge solids should sell for: 1/5x11 + 4/5x20 = $18.20 per ton (dry solids) or $0.77 per ton (heat-dried sludge). Wet sludge therefore has a potential of recovering $0.77 per ton (of wet sludge), bringing the cost of heat drying down to $2.00 - $0.77 = $1.23 per ton (of wet sludge).

Rating: mechanical dewatering ($1/ton): 8/8.
air drying ($1/ton): 8/8.
heat drying ($1.23/ton): 4/8.

Waste Reduction. Mechanical dewatering and air drying reduce the quantity of sludge considerably since the bulk of the water is removed from the sludge by these processes. However, there is negligible reduction in the solids content as there is little resource value in this material which has to be disposed of.

Heat drying reduces the quantity of sludge by an even greater amount than the above two processes and, if marketing of the resulting product is successful, can reduce the solids content quantity to be disposed of as well. However, experience with heat-dried sludge has shown that, except in a few instances, this material has not been commercially viable.

Rating: mechanical dewatering: 1/8.
air drying: 1/8.
heat drying: 1/8.

Flexibility. These sludge drying systems must be located at or near sewage treatment plants as the cost of transporting sewage sludge of 96 percent moisture content is several times higher than the cost of transporting sludge with a moisture content even as high as 75 percent.

The market prospects for soil conditioner from sludge are not very attractive. This material cannot be easily stored, transported, or marketed unless it has been heat dried, and even heat-dried sludge needs extensive marketing if it is to avoid being simply landfilled.

Rating: mechanical dewatering: 2/8.
air drying: 2/8.
heat drying: 4/8.

State of Development. These processes are state-of-the-art technology.

Rating: mechanical dewatering: 8/8.
air drying: 8/8.
heat drying: 8/8.

Conservation of Natural Resources. The resource recovered is soil conditioner, without significant nutrient content.

Rating: mechanical dewatering: 2/8.
air drying: 2/8.
heat drying: 2/8.

Weighted Totals:

Mechanical dewatering:
8x33 + 1x28 + 2x12 + 8x19 + 2x8 = 484/800.
Air drying:
8x33 + 1x28 + 2x12 + 8x19 + 2x8 = 484/800.
Heat drying:
4x33 + 1x28 + 4x12 + 8x19 + 2x8 = 376/800.

d. Plastics Remolding

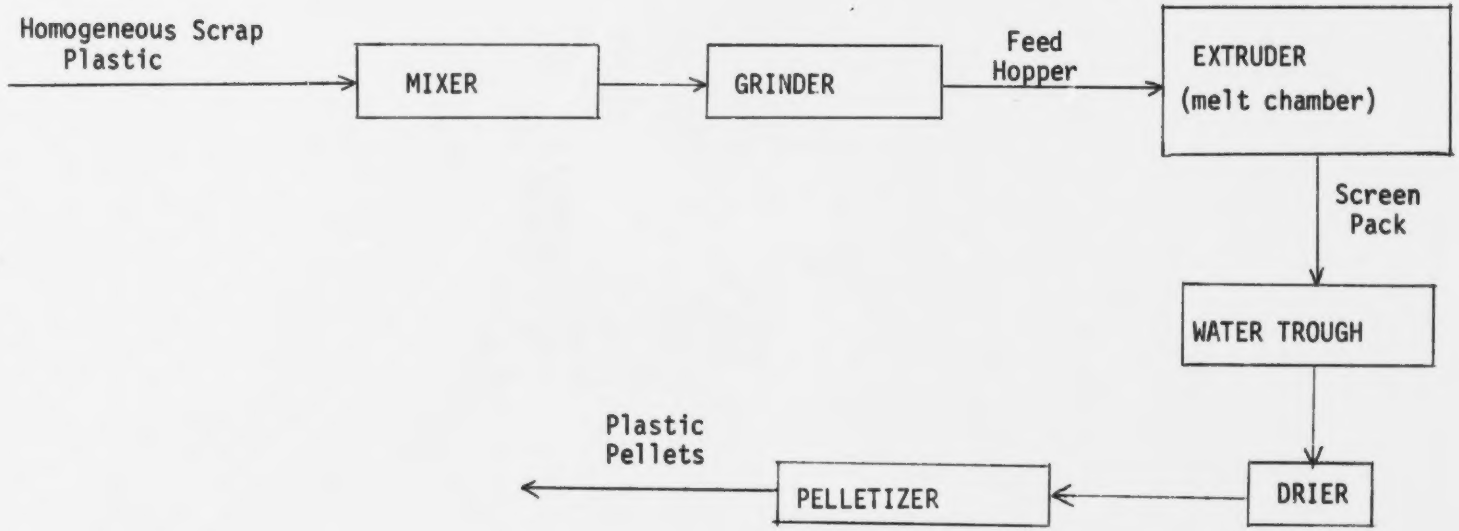
The state-of-the-art of plastics recycling has concentrated on approximately 80 percent of plastics which can be remelted again after forming and are labeled "thermoplastics." The remaining 20 percent "set" after forming and are labeled "thermosetting" plastics. This category includes phenolics, polyesters, epoxy, and other materials. Experiments to recycle thermosetting plastics by reducing them with a solvent and then reconstituting the polymer are now under way, but are not as developed as the thermoplastic remolding operation described below.

i. Process Description

Primary polymer production and fabrication wastes, unless they are immediately reused in the plant where they occur or are disposed of, are acquired by plastics scrap dealers or processors who specialize in regrinding scrap, washing, color blending, remelting, or

FIGURE 26

FLOW DIAGRAM FOR PLASTICS REMOLDING



just reselling scrap. Specifications for various end uses can be met by mixing in additives or impact modifiers to upgrade the recycled plastic.

Typical of equipment used by reprocessors are pellet-producing extruders. The extruder is usually preceded by a grinder; then a blower carries ground material into a hopper fitted with an augur which feeds the extruder. Plastic is melted in the extruder and then extruded through a screen-pack and strand die into a water trough. Temperature on the extruder side of the strand die is about 300 degrees F; the water trough temperature is about 90 degrees F. The plastic strands are passed through an air stripper or dryer and then pelletized.

The pelletized plastics can then be used in conventional molding machines to make products similar to those made with virgin material, or, if the pellets are contaminated with foreign material or other plastics, products requiring low specification material are made.

A flow diagram for a plastics remolding operation is presented in Figure 26.

Extrusion equipment ranges in cost from $45,000 at a 650-pounds-per-hour capacity to $60,000 at a 1000-pounds-per-hour capacity. Operating and maintenance costs range from 1¢ to 3¢ per pound. The total cost for the extrusion process averages 5¢ per pound.

One pound of plastic scrap yields one pound of usable plastic pellets in the extrusion process.

ii. Marketing

Primary polymer production and fabrication wastes, unless they are immediately reused in the plant where they occur or are disposed of, are acquired by plastics scrap dealers or processors who specialize in regrinding scrap, color blending, remelting, or just reselling scrap.

The function of plastics scrap dealers has traditionally been one of moving scrap from a producer to user without any intermediate processing. Sources from which scrap is purchased are the primary polymer producer and the fabricator. Those buying from a scrap dealer would be molders, extruders, reproccessors, and overseas dealers. This last source is rapidly diminishing as AID will no longer financially support the exportation of secondary plastic materials and overseas dealers are finding their supplies of plastic scrap at home.

Reprocessors have a large number of functions. Besides acting as scrap dealers to move plastic wastes, processors frequently operate on a contract basis, returning wastes to the organization which provided them, reformulated into a product that can be reused. These processors also supply manufacturers that use scrap plastics as an input material.

As plastics become available from the solid waste stream, the scrap dealers and reprocessors who have normally handled secondary plastics would be the logical customers for this new source of plastics. Scrap plastics have commanded a price of 2¢ per pound upwards, depending on the plastic, its contamination level, and the current market for that particular plastic. Plastics from refuse are likely to sell for approximately 25 percent less because of their contaminated condition which limits their use and which may require more extensive processing.

iii. Evaluation

Plastics remolding is currently applied only to fairly clean, homogeneous plant scrap. However, adaptation of present-day technology to handling plastic wastes as sorted from a municipal solid waste stream is not expected to be difficult. Separation techniques to obtain plastics by polymer type are, however, still in the developmental stage. The evaluation presented here for plastics remolding is based on the assumption that plastics are separated from municipal wastes by polymer type and the technology to remold such a contaminated material is available. Since a plastics sorting and remolding system would be only a small part of a complete waste treatment system, numerical ratings are not given in this evaluation; the technology should not be directly compared with other complete systems.

Net Costs. The credits for plastic remolding are dependent on the particular plastic being recycled. This could range from 10¢ per pound for polyethylene to over 50¢ per pound for ABS. The total cost of melting and reextruding plastics averages around 5¢ per pound. The cost for separating plastics from municipal solid wastes is projected at 5¢ per pound. Thus the cost for this process is 5 + 5 - (10 to 50) = 0.0¢ to a profit of 40¢ per pound of plastic.

The total cost per ton of municipal waste may vary widely, depending upon the mix of types of plastics present in the waste, the added costs of disposing of the non-plastic wastes, and the marketing and distribution costs of the reclaimed plastics.

Waste Reduction. Only the plastics content (approximately 2 percent) of municipal refuse is being recovered.

Flexibility. The plastics remolding plant could be located anywhere a normal solid waste disposal facility would be located (landfill, combustion plant, etc.). However, markets for reclaimed plastics (principally fabricators) appear to be concentrated in specific locations in the United States and, excepting for these areas, transportation costs may invalidate the future prospects for this technology, especially if disadvantageous freight rates for secondary materials are allowed to continue.

Although this resource is easy to store, market fluctuations may reduce the flexibility of effectiveness and economics in its dependence on waste stream composition. However, with future projections indicating a rapid rise in the percentage of plastics in municipal refuse, this system can increase in scale size easily with add-on equipment.

State of Development. The equipment for separation of plastics is in the developmental stage. The equipment for remolding contaminated plastics could be adapted from already existent equipment being used for homogeneous, relatively clean, plant scrap.

Conservation of Natural Resources. Although the quantity of resources recovered is extremely small, plastics are made from a nonrenewable source (petroleum) and recovery of this material would help to conserve this basic feedstock.

5. Application to Land Surface

Organic waste materials may be disposed of by spreading them directly on fields as a soil conditioner, fertilizer, or both, with little or no prior treatment. This method has traditionally been the primary means for recovering resources from animal manure and still accounts for the disposition of virtually all crop field residue. Municipal waste has been used successfully for soil beneficiation without prior composting. Spraying liquid sewage sludge on fields has promising possibilities. Field spreading as applied to the three major waste streams, municipal waste, animal manure, and sewage sludge, will be discussed and evaluated in three parts below.

a. Plowing Shredded Municipal Wastes into the Soil

Composting of municipal waste is not economical if the compost product cannot be sold, and is not an effective waste management scheme if the unsold compost is not effectively disposed of. Researchers at the University of California at Davis[137] are investigating a scheme of disposing of compost on agricultural land, improving the economics by using only a "rough compost" rather than a "finished compost." A "finished compost" is made by grinding, separation of non-compostables, and aerobic microbial decomposition, but the "rough compost" employed in the scheme at Davis is only ground. The ground wastes are spread upon and tilled into agricultural land so that soil microbiological processes can stabilize the wastes and the organic content of the waste will, in the long run, contribute to soil structure.

The experimenters at Davis visualize applying wastes to a specific location once or twice a year at rates up to 200 tons per acre-year. Higher rates were tried, but were found to lead to nuisance problems of refuse blowing away, attracting pests, or producing odors. Rates of 300 tons per acre-year and 400 tons per acre-year could only be acceptably applied if the top six inches of soil were scraped away and replaced on top of the deposited wastes. Because such methods would require specialized equipment and costly effort, 200 tons per acre-year is considered the maximum permissible rate of application of the ground wastes.

The University of California has estimated the costs involved in this waste management scheme for handling 200 tons of refuse per day (collected from a population of 52,000, five days a week), and they are summarized here:

1. Refuse grinding. From the experience obtained in the Madison, Wisconsin practice of grinding before landfilling, cost is taken to be \$2.60 per ton of refuse.

2. Field spreading and tilling. It is assumed that the grinding station is next to the accepting field, and that each acre of field receives 200 tons of refuse and then is irrigated three times, disked once, and fertilized with nitrogen before it accepts another load of refuse a year later. \$1.53 per ton of refuse.

3. Land use charges. This is certainly the most variable cost. If it is desirable to use a healthy soil to secure and degrade the waste, the land would probably be of

value for raising crops and thus expensive. The University of California calculation was based on purchasing land for $1,000 per acre and selling it after 20 years for $500 per acre. $1.06 per ton of refuse.

4. Burial of objects rejected by the grinder. Five percent of refuse at $4 per ton. $0.20 per ton.

The total of these costs is $5.39 per ton. However, the cost of hauling to the site must be added since the distance will probably be greater than the distance to possible landfill or incineration sites. If the fields were 20 miles from the city and hauling costs were 8¢ per ton-mile (U.C. estimate), the added costs would be $1.60 per ton. After the projected 20-year lifetime of the refuse-accepting ground, there will be considerable accumulation of non-degradable plastics, glass and metals. These may amount to 20 percent of the incoming refuse and so accumulate to 37 pounds per square foot, at which time the land would probably look like an open dump. The U.C. researchers suggest that the accumulated debris may then have to be picked up. However, it would probably be more economical to separate the non-compostables right after the grinding of the refuse, perhaps by air classification for $1 per ton. The additional costs for hauling and separation raise the total cost estimate to $8 per ton of refuse. The non-biodegradable wastes must still be salvaged or dumped.

Dr. Geoffrey Stanford,[138] Director of the Environics Center at St. Edwards University in Austin, Texas, has initiated a similar field trial and study of applying ground solid waste and sewage sludge. Some over-farmed land in Texas is now of such poor tilth that the application of these wastes may lead to significant appreciation of the land. The overall economics of this waste disposal system are greatly influenced by the attitude taken toward the effect the wastes have on the land--a beneficiation or depreciation. It remains to be seen whether landowners would purchase the treated waste rather than adopt more conventional and similarly inexpensive beneficiation techniques such as green manuring or the spreading of livestock manure. In some locations where seriously depleted land does exist near a municipality, the U.C. estimate of land depreciation may be pessimistic, but applied to a major fraction of the municipal solid waste stream in the country as a whole, the U.C. attitude would seem realistic.

There are some other features of this waste disposal system that limit its flexibility. First, it cannot be applied where the ground freezes or is snow-covered in the winter. Second, it cannot be applied on days when the soil is too wet to permit the movement of heavy equipment distributing the wastes. Third, the land requirements are great: at the maximum application rate of 200 tons per acre-year, a city of 500,000 would require 2,600 acres, and

TABLE 78

COST OF LIQUID MANURE DISPOSAL FROM FULL CONFINEMENT SYSTEMS

	Tons of Manure/Year	Fixed Costs $/Ton	Operating Costs $/Ton	Annual Volume of Manure Divided by Storage Capacity				Total $/Ton
				10,	8,	6,	4	
Dairy Cows								
62	677	1.03	0.30		.16,	.21,	.34	1.49-1.67
124	1354	0.52	0.30		.16,	.21,	.34	.98-1.16
186	2031	0.34	0.30		.16,	.21,	.34	.80- .98
248	2708	0.26	0.30		.16,	.21,	.34	.72- .90
Swine								
235	300	0.70	0.44	.14,	.16,	.21,	.34	1.28-1.48
470	600	0.35	0.44	.14,	.16,	.21,	.34	.93-1.13
705	900	0.23	0.44	.14,	.16,	.21,	.34	.98-1.01
940	1200	0.26	0.33	.14,	.16,	.21,	.34	.73- .93
1175	1500	0.21	0.33	.14,	.16,	.21,	.34	.68- .88

Source: From Morris, W.H.M., "Economics of Liquid Manure Disposal from Confined Livestock," in the proceedings of the National Symposium on Annual Waste Management held at East Lansing, Michigan, May, 1966.

just over a million acres would be needed to cope with the entire domestic and municipal waste load. Fourth, on a large scale, wherever the exposed wastes are highly visible, the scheme might be unattractive to the public.

If this waste management scheme does find acceptance, probably on a small scale in a location that overcomes the difficulties described above, a further precaution will have to be taken. If the disposal site is to be used for crop production, since this scheme will involve placing mixed wastes of grossly predictable, but in detail uncontrollable, constituents directly into a supporting element of the human and livestock food chains, consideration will have to be given to the possibility of movement through these food chains of toxic materials originating in the waste stream.

Because this technology is anticipated to find acceptance only on a small scale for the reasons described above, it was not rated numerically along with other widely applicable management or extraction technologies.

b. Application of Manures to the Land Surface

Much of the animal manure generated in the United States is spread on agricultural land. On pasture or rangeland the livestock itself performs some of the spreading operation. However, because defecation tends to take place near feeding and watering places, in most instances spreading manure away from shelters, feeding stations and watering holes must be done by the livestock owner and is more costly than the value of the manure as a fertilizer would justify. On soils of good tilth, current agricultural practice is to use only chemical fortification which can be accomplished economically through the distribution of lightweight, concentrated, synthetic fertilizer. Accordingly, manure is sometimes spread over only small areas at rates high enough to pollute surface runoff or cause nitrogen toxicity of crops. In other places it may be stockpiled and not spread at all. Even though proper spreading of manure is usually not profitable, it should continue to be viewed as a sanitary method of disposal that conserves some of the resource value of the manure.

Most manure is spread in a solid form. However, where full confinement systems are used for managing swine and dairy cattle, spreading of manure as a liquid slurry is occasionally replacing solids handling techniques. Liquid handling systems are being introduced because labor requirements are reduced, fertilizing constituents are better retained and it is possible to avoid hauling manure at periods of peak labor demand for planting and harvesting. The costs of operating a system involving liquid storage either beneath the floor, in a concrete pit or in a lagoon outside the shelter, transporting it (up to 800 yards) and spreading from a vacuum wagon are compiled in Table 78 from Morris.[139]

The value of the manure slurry applied to a field that does not require additional organic matter is equal to the cost of an equivalent amount of chemical fertilizer supplying the nitrogen, phosphorus, and potassium that would produce a similar effect on crop yields. This value of the slurry is influenced by the nitrogen, phosphorus and potassium content of the manure at the time of application, the availability of these elements and losses due to unseasonal or unbalanced application. Morris's estimates of the value of manure slurries are presented in Table 79. Apparently the liquid handling system has a potential for being profitable when applied to swine wastes. However, Casler[140] has argued that strong odors produced in the anaerobic storage of the liquid manure may limit the applicability of this system.

The optimum rates of application of manure for soil beneficiation must, of course, be determined for each soil type and locality. However, typical annual rates might be 15 tons of cattle manure, 4 tons of poultry manure or 5 tons of swine manure per acre, and these rates can be used to estimate the land requirements for beneficial spreading of manure. It becomes immediately obvious that sufficient land is not available near very large confinement operations. Although 200 dairy cows generating 2000 tons of manure per year would require only 134 acres, a poultry farm with 100,000 birds generating 4560 tons of manure would require 1140 acres, a swine feedlot with 10,000 animals producing 12,800 tons of manure would require 2560 acres, and a beef cattle feedlot with 10,000 head generating 100,000 tons of manure would require 6700 acres.

The wastes from large animal populations must then be managed by more novel techniques. Because of these limitations of scale, the field spreading of manure was not evaluated numerically along with other large-scale management or recovery technologies.

TABLE 79

RANGE IN VALUE OF MANURE SLURRIES ($ PER TON)[a]

	Swine	Cow
N	.21-.63	.09-.21
P	.22-.67	.03-.10
K	.13-.25	.10-.19
Total	.56-1.55	.22-.50

[a] Based on 1966 costs of 7, 8 and 4.2¢ per pound for nitrogen, phosphorus and potassium. Estimate from Morris, W.H.M., "Economics of Liquid Manure Disposal from Confined Livestock," in the proceedings of the National Symposium on Annual Waste Management held at East Lansing, Michigan, May, 1966.

c. Spray Irrigation of Sewage Sludge

Spray irrigation is basically land disposal of liquid-digested sludge to fertilize grass or agriculture crops, and to condition soils on sandy park land. This process is very common among smaller waste treatment plants and even large cities such as New York and Chicago have used this technique in conjunction with land reclamation projects.

Digestion is always required prior to spray irrigation. Usually storage lagoons are also necessary as adverse weather conditions may limit handling wet sludges out onto farmland. The actual spray irrigation on the site can take a number of forms. Shallow trenches may be dug and filled with digested sludge which is covered with soil to prevent nuisance conditions. Alternatively the liquid sludge can be injected into the subsoil under pressure. Many operations spray the sludge from tank wagons.

On farmland it is best to clear previous crops, plow deeply forming furrows to contain the liquid sludge. Alternatively, a shallow layer is spread, dried, and harrowed, followed by a deeper application of sludge with drying and harrowing. Multiple applications such as these form thin sludge layers that are easily worked into the soil.

Sludge loading rates varying from 100 to 300 dry tons per acre per year have been reported. Studies at San Diego have indicated that loadings of 50 dry tons per acre, every alternate year will produce superior crops.[141]

A town of 150,000 people produces 24 tons of dry solids of sludge per day, or 8750 dry tons per year. At this rate this town could dispose of all its sludge on 350 acres, with no more land ever needed, presuming constant population and sludge loadings.

Transportation of sludges to areas where suitable land is available is the major burden of this system of sludge disposal. For a short haul, trucks may be used, and this cost averages $0.75 per ton of wet sludge. For longer hauls, pipelines and rail-haul, at approximately $0.14 per ton of wet sludge, could be used.

The total costs of spray irrigation are highly variable, depending upon land values, distance of disposal site, transportation costs. Based on the experience of the city of Chicago, these costs have been assumed to average $1.70 per ton of wet sludge, for an average distance to the disposal site of 160 miles.

Evaluation: Spray Irrigation of Sewage Sludge

Net Cost: rating 4/8.

Waste Reduction: rating 8/8.

Flexibility: Land is needed away from the generating area. Rating 2/8.

State of Development: rating 8/8.

Conservation of Natural Resources: Some chemical fertilizer conserved. Rating 2/8.

Weighted Total:

4x33 + 8x28 + 2x12 + 8x19 + 2x8 = 548/800.

6. Land Disposal/Reclamation Techniques

Land disposal is the only method for total disposal of all solid wastes. Final disposal remains a problem even after resource recovery processing because virtually all methods of processing or recycling of solid wastes leave some fraction of waste residue.

Landfilling is considered in this study even though its classification as a resource recovery process is somewhat artificial. Landfilling may be looked upon as a method for recovering resource value from solid wastes by considering wastes to be a fill material being used for land reclamation.

Landfilling of biologically and chemically inert material properly done is a comparatively cheap and ecologically sound method of waste disposal. This process is in widespread use and is the base-level technology against which other disposal methods, with or without resource recovery, are compared.

a. Landfilling Unprocessed Municipal Refuse

i. Process Description

Sanitary landfills disposing of unprocessed municipal wastes, if properly designed and operated, should not incur any serious environmental problems. Site selection requires consideration not only of the proposed fill area but also of borrow areas (for cover material), access roads, grades for proper drainage, and special drainage facilities. It also requires geological investigations, including on-site soil borings to determine the potential of water pollution and lateral gas movements in the area. An important consideration is whether a sufficient quantity of suitable quality cover material is available on the fill site, and its ease of excavation, or whether other areas will have to be disturbed to obtain cover material.[142]

There are a large number of methods of operating a successful sanitary landfill, varying according to local conditions such as terrain and climate.[143] However, these are usually a variation on one of three basic procedures:[144] (1) the area fill, best suited for flat areas with high ground-water tables, in which refuse is laid on the ground in lifts (layers) of equal height; (2) the trench fill, best suited for flat land with low ground-water tables, in which trenches are excavated, refuse put in the trenches, and the excavated material used to cover the refuse, thus minimizing haul distance for the cover material; and (3) the ramp or slope method, best suited for uneven terrain, in which solid wastes are dumped on the side of an existing slope and covered with material usually obtained from just ahead of the working face of the fill. Landfills of all types are usually operated by spreading refuse in thin layers on the ground. A bulldozer or other piece of earth-moving equipment (perhaps the same one that spread the refuse) then passes over the refuse, compacting it. At the end of a day's operation, a six-inch layer of soil is placed on top of all the refuse. When the refuse has ultimately been built up to a projected maximum height (50 to 60 feet above ground level is not uncommon), a final two-foot layer of soil is applied. This can then be seeded over with grass and other vegetation.

In the context of land reclamation, landfills so prepared can be used for golf courses, parks, and other open-air land uses.[145] The land will settle considerably over time, the amount of settlement depending upon a large number of parameters. However, a settlement of as much as several feet in the first year, lessening over time to as little as a fraction of an inch per year after 20 years, is not uncommon. This means that structures cannot be immediately built on landfills. However, after a period of time, when settling has been shown to be considerably reduced, structures ranging from parking lots to high-rise buildings can be built on this land. Precautions must be taken to permit the escape of gases that continue to build up in the landfill. Gases trapped in the basements of houses have led to serious explosions. Thus land which may originally have been low lying, marshy, or unusable for some other reason can be put to a constructive use by landfilling with refuse. A flow diagram for the landfilling of unprocessed refuse is shown in Figure 27.

As sites for this process technology begin to be moved further and further away from points of solid waste generation (because of nuisance potential and rising prices of land), transportation costs appear to be making landfilling, traditionally the cheapest and most convenient method of solid waste disposal, look economically

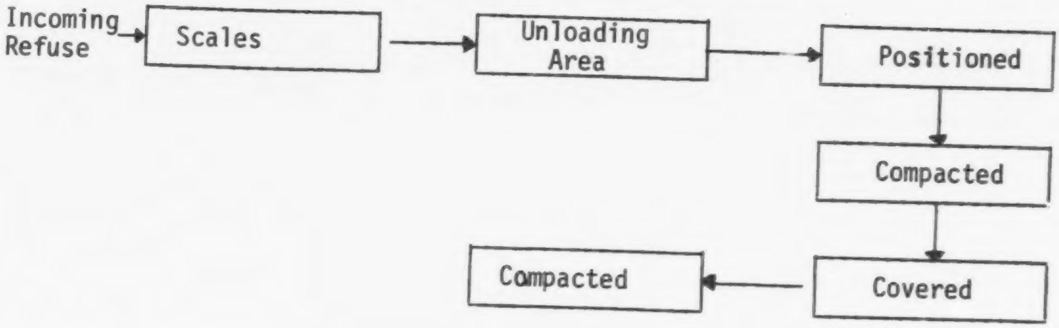


FIGURE 27

FLOW DIAGRAM FOR THE LANDFILLING OF UNPROCESSED REFUSE.

less attractive than more sophisticated, more capital-intensive systems that can be located closer in to points of solid waste generation.

The cost per ton of refuse landfills varies from $1 to $5, depending upon a large number of factors (type of terrain, cost of land, labor, climate, aesthetics of the operation, regional considerations, etc.). The capital cost of a 400-ton-per-day landfill operation averages $680,000, which amortizes to $0.80 per ton. Operating costs at this scale range from $1.50 to $3.30 per ton, and total costs from $2.30 to $4.00 per ton.

Materials Balance

1 ton solid waste ⟶ 1 ton fill material
1 cu yd solid waste ⟶ 1/3 cu yd fill material

ii. Evaluation

Net Costs. As no resource is being recovered, there are no credits for this technology. The value of the land after it has been filled with refuse is a highly variable parameter. The trend towards designating land so used as public recreation facilities after the landfilling operation is complete indicates that a value in general economic terms cannot be assigned to this land. The net cost therefore remains at $2.30 to $4.10 per ton.

Rating: 8/8.

Waste Reduction. If this technology is viewed as land reclamation, then there is a 100 percent waste reduction. However, as is more often the case, if this technology is classified as a disposal technique, then no waste reduction has been effected.

Rating: 1/8.

Flexibility. Crude landfills have caused serious problems such as spontaneous fires, health hazards (from an accumulation of rodents, insects, birds, etc.), unsightliness, and general nuisance (such as from blowing paper). As a result all landfills have a poor reputation and locating sites for landfills anywhere close to the communities that they are serving has become a major problem. Thus landfills are being located further and further away from solid waste generation points. This has stimulated the growth of materials handling solutions, such as transfer stations, tc the long-haul problem, which limits somewhat the flexibility of this technology.

However, landfills can absorb almost any solid waste material, are insensitive to changes in solid waste composition, can store materials until technology progresses to a stage where it is ready to utilize these materials, and provide adequate space on their own sites for any resource recovery equipment that is desired.

Demonstration that landfills can be sanitary should improve the rating on this technology, although rising land prices may nullify the benefits of public acceptance of landfilling.

Rating: 4/8.

State of Development. Sanitary landfills are a state-of-the-art technology.

Rating: 8/8.

Conservation of Natural Resources. If considered as a disposal technology, there is no conservation of natural resources. As a land reclamation technique, the refuse substitutes for dirt, gravel, rock, etc., of which there is plentiful supply already existing.

Rating: 1/8.

Weighted Total:

$$8\times33 + 1\times28 + 4\times12 + 8\times19 + 1\times8 = 500/800.$$

b. Landfilling Shredded Refuse

i. Process Description

The first major experiment in landfilling shredded refuse in the United States has been carried out over several years at Madison, Wisconsin.[146] The process consists of a conventional solid waste transfer station at which refuse from collection vehicles is fed into a vertical shaft grinder. The grinder consists of hammers mounted on a central rotating axis in such a manner that the distance between the hammers and the outer cylinder successively diminishes through the height of the grinder, so that refuse is reduced in size not only by the cutting edges of the hammers, but also by being pressed against the sides of the containing cylinder. Refuse moves downward through the grinder by the action of gravity. Variable-size grates near the bottom of the grinder regulate the size of particles that ultimately leave the grinder. Bulky items that cannot be reduced by the grinder are ballistically ejected.

Various configurations of shredders and grinders are available for this purpose. After refuse is reduced in size, it is transported to a landfill in transfer trailers and landfilled in a conventional manner.

Shredding refuse changes its characteristics.[147] These changes are attributed to organic, putrescible matter being spread out and partially absorbed rather than being lumped together and thus possessing a higher nuisance value. Some of the processing benefits accruing from shredding are:

(1) Daily cover of refuse is not required.

(2) The shredded refuse compacts more readily than the unshredded refuse and, with no intermediate cover, occupies less volume in a landfill than unshredded refuse.

(3) Shredded refuse minimizes the paper blowing problem traditionally associated with unshredded refuse landfills.

(4) Shredded refuse supports traffic operations during wet weather.

(5) Shredded refuse has little or no odor.

(6) Shredded refuse does not readily support insects or rodents.

(7) Shredded refuse has little tendency toward spontaneous combustion or spreading and maintaining fire.

A flow diagram for the landfilling of shredded refuse is shown in Figure 28.

Cost figures for a shredded refuse landfill were developed for the Madison, Wisconsin operation, using a commercial pulverizer, presuming operation by a municipality, at a 172-ton-per-day capacity (one pulverizer working two eight-hour shifts) and assuming that the landfill is within two miles of the pulverizer site and can be operated without cover until the final grade is reached (Table 80).[148]

Capital costs range from $1000 to $7000 per ton of daily rated capacity.

Operating costs range from $1 to $4 per ton.

Total costs run approximately $3 to $10 per ton.

The capital cost of a 400-ton-per-day shredding and landfilling operation averages $1,400,000, which amortized to $1.10 per ton.

FIGURE 28

FLOW DIAGRAM FOR THE LANDFILLING OF SHREDDED REFUSE

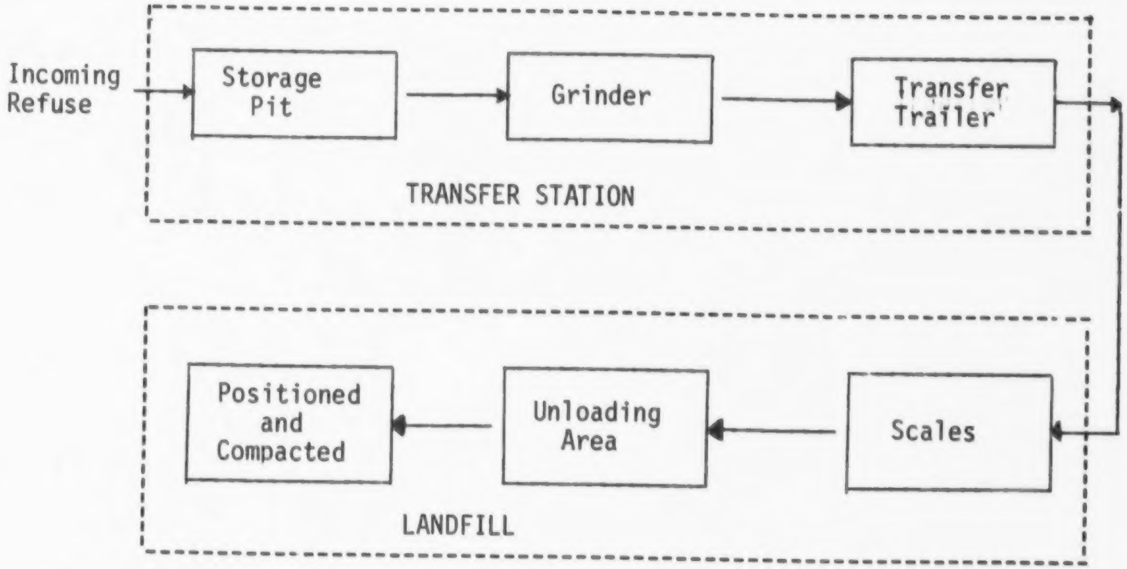


TABLE 80

SHREDDED LANDFILL COSTS

Manpower - Per Shift	No.	Hourly Rate[a]	Daily Rate	Cost /Ton
Plant Supervisor		$5.40		
Front End Loader Operator	1	4.70	$37.60	
Mill Operator	1	5.00	40.00	
Mill Laborer	1	3.00	24.00	
Truck Driver		4.50		
Landfill Operator	1	4.70	37.60	
	4		$139.20 86 tons	$1.619

[a] Includes 25% fringe benefits, no overtime.

Equipment	Appr. Cost	Depr. Period	Amort. Chgs[b]	Cost /Ton
Pulverizer	$ 75000	15	$ 7226	
Front End Loader	15000	8	2321	
25 Yd Packers-Transport to Fill	30000	8	4642	
Scale	7000	20	562	
Compactor-Grader	25000	8	3868	
Land_____Acres				
Steel Bldg w/Slab & Erection	30000	20	2408	
Land Preparation, Drives, Landscaping	20000	40	1166	
Installation, Wiring, Heating, Plumbing	10000	20	803	
Machinery Foundation	10000	40	583	
	$222000		$23579 43000 tons	.548

[b] On annual basis at 5% and no salvage value.

Operating Charges	Cost /Ton
Packers-Maintenance & Operation	.10
Compactor Maintenance & Operation	
Front End Loader Maintenance & Operation	.1051
Services-Heat, Power, Water	.0800
Mill Power - 10 Kwh/Ton	.1540
Mill Maintenance, including Hammers & Grates	.3466
	.6837
Total	$2.9507

Source: From equipment literature, The Heil Co., Milwaukee, Wisconsin.

Operating costs (shredding and landfilling) range from \$2.40 to \$4.40 per ton, and total costs \$3.50 to \$5.50 per ton.

Materials Balance

$$1 \text{ ton solid waste} \longrightarrow 1 \text{ ton fill material}$$
$$1 \text{ cu yd solid waste} \longrightarrow 1/5 \text{ cu yd fill material}$$

ii. Evaluation

Net Costs. Since no resources are recovered, the net cost = total cost = \$3.50 to \$5.50 per ton.

Rating: 8/8.

Waste Reduction. Shredded refuse compacts somewhat better than loose unprocessed refuse, but there is no additional waste reduction in terms of weight.

Rating: 1/8.

Flexibility. This is similar to landfilling unprocessed refuse, excepting an additional burden of locating a shredding plant is now included.

Rating: 4/8.

State of Development. This is a state-of-the-art technology.

Rating: 8/8.

Conservation of Natural Resources. This is similar to landfilling unprocessed refuse.

Rating: 1/8.

Weighted Total:

$$8 \times 33 + 1 \times 28 + 4 \times 12 + 8 \times 19 + 1 \times 8 = 500/800.$$

c. Landfilling Baled Refuse

i. Process Description

The reasons for baling wastes (and sometimes encapsulating them, usually in plastic) are that less landfill space will be required and that there is a lesser possibility of contaminating ground water.[149] Other environmental problems are also expected to be minimized--no blowing papers, reduced insect and rodent populations since access to the organic matter in the refuse has been made more difficult, no lateral movement of gases, etc. Hopefully encapsulated bales will not require daily cover, although this has yet to be established. Handling problems associated with the large bales must be considered, especially placing the bales in a landfill so that they really do occupy less space than loose refuse would.

Conserving landfill space is a major concern in all landfilling methods. Also the higher the densities achieved initially, the lesser the settling expected later. Average densities of refuse are listed below:

Average density loose refuse:	200 lb/cu yd
Average density refuse in packer truck:	400 lb/cu yd
Average density refuse in loose refuse landfill:	600- 800 lb/cu yd
Average density shredded refuse in landfill:	1000-1200 lb/cu yd
Average density baled refuse in landfill:	2000 lb/cu yd

Shredded and baled landfills obviously make more efficient use of land space than a loose refuse landfill.

A Japanese company has developed a process for producing high-density bales from refuse, for use as building blocks and land reclamation purposes.[150] Evaluation of this process has indicated its general unsuitability for both purposes. The process has thus been classified as a land disposal process rather than as a true resource recovery system.

A flow diagram for the landfilling of baled refuse is shown in Figure 29.

Total costs average one dollar higher than the shredding operation, and two dollars higher than loose refuse landfilling as the basic costs for these two less expensive processes are also incurred in the baling process, along with the extra cost of the baling operation. However, some cost savings are expected because of less land space required.

The detailed cost figures presented in Table 81 were developed for a baler which produces 40 bales per hour, each bale 1.33 cubic yard (3' x 3' x 4') in volume and 1.4 tons in weight, for a total of 896 tons per day on a 16-hours-per-day basis.[151] The figures assume 90 percent utilization, or 230,630 tons per year, of the baling plant during this time (the remainder of the time for unexpected breakdowns or a slack period in the intake of refuse).

FIGURE 29

FLOW DIAGRAM FOR THE LANDFILLING OF BALED REFUSE

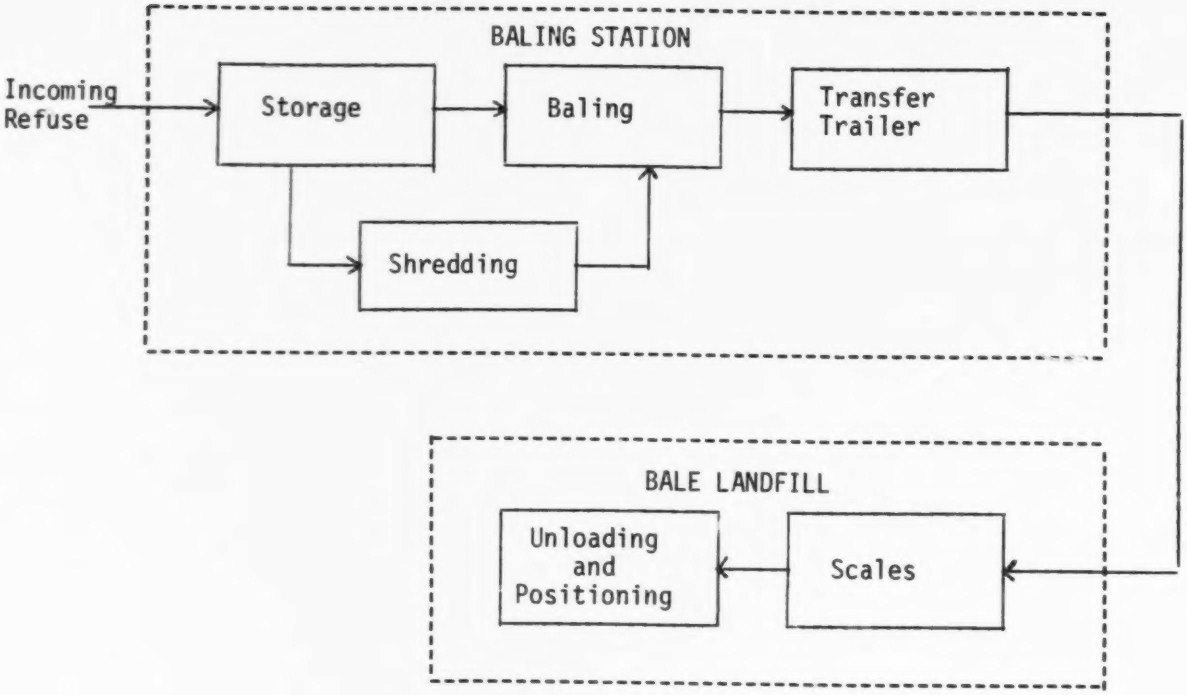


TABLE 81

COSTS OF BALED LANDFILL (INCLUDING BALING PLANT)

	Per-Ton Cost
Labor	.6030
Overhead	.1665
Maintenance - Parts Reserve	.0780
Heat, Light, and Power	.1561
Contingencies	.1107
Facility and Equipment	.4661
Interest Cost	.2424
Total Per-Ton Cost	1.8228
Placing Bale in Landfill and Ultimately Covering	1.75
Total Per-Ton Cost of Baling and Landfilling	3.5728

Note: Cost of transportation from baling plant to landfill is a variable depending upon distance and must be added on to the figure above.

Source: From Scott, H.C. Presented at Seminar on High Compression Baling of Solid Waste, APWA Congress, Philadelphia, September 15, 1971.

The capital cost of a 400-ton-per-day baling and landfilling operation averages $1,000,000, which amortizes to $0.90 per ton. Operating costs (baler and landfill) are estimated at $3.50 per ton, and total costs at $4.40 per ton.

In the Japanese process, to use compressed refuse as building blocks, an outer covering shell must be utilized (to impart integrity to the bales). The cost of this encapsulation ranges from a low of $3 per bale for chicken wire mesh to $50 per bale for sheet metal. In addition, to build the baling plant (at a capital cost of $8000 per ton/day capacity), an amortization cost (10 percent at 20 years) of approximately $2 per ton or $10 per bale will be incurred. Operating costs are at least another $1.50 to $2 per ton, or up to $10 per bale. Thus, the total cost of a refuse building block will be considerable. Handling costs for the bulky blocks will also be high.

The capital cost of a 400-ton-per-day landfilling operation utilizing the Japanese process for high-density baling is $3,200,000, which amortizes to $3.00 per ton. Operating costs are $8.00 per ton, and total costs are $11.00 per ton.

Materials Balance

1 ton solid waste ⟶ 1 ton bale

1 cu yd solid waste ⟶ 1/10 cu yd bale

ii. Evaluation

Net Costs. Since there is no resource recovered, the net cost = total cost = \$4.40 per ton for baling and landfilling, and \$11 per ton for the Japanese process of high-density baling and landfilling.

While use of the bales should lengthen landfill site life by at least three times that of conventional refuse fills, the cost of landfilling is likely to increase due to the difficulty of handling and placing the bulky bales.

In the Japanese high-density baling process, comparing refuse block costs with those of conventional blocks, a 5'x5'x5' block weighing 5 tons, and encapsulated in concrete, will cost approximately \$40, or \$8 per ton to produce. Pricing information for 5'x5'x5' concrete blocks is not available, but a 12"x8"x6" hollow concrete block costs 40¢ and an 8"x8"x6" solid concrete block costs 46¢. A 5'x5'x5' volume of these blocks would cost between \$60 and \$80 but have far greater flexibility for building purposes. Transportation and handling costs would further reduce the viability of the bales. In any case, the uncertainty surrounding the stability of the bales indicates that more experimentation will be needed before these blocks become commercially acceptable as riprap material.

Ratings: landfilling baled refuse: 8/8.
landfilling high-density bales
(Japanese process): 2/8.

Waste Reduction. Although there is considerable volume reduction, the weight of wastes remains the same.

Rating: 1/8.

Flexibility. This is similar to landfilling unprocessed refuse, except that a baling plant must now be included. Also the terrain or the landfill may need to be shaped so that the bales may be placed on it with ease. There is some difficulty about handling the bales, especially if the integrity of the bale is in doubt.

The slower rate of decomposition in the bales means that a land reclamation site using bales will not achieve stability as rapidly as a conventional landfill site. Also, there appears to be an additional danger of spontaneous combustion.

Rating: 4/8.

State of Development. State-of-the-art technology.

Rating: 8/8.

Conservation of Natural Resources. None.

Rating: 1/8.

Weighted Totals:

Landfilling baled refuse:
$8 \times 33 + 1 \times 28 + 4 \times 12 + 8 \times 19 + 1 \times 8 = 500/800.$
Landfilling high-density bales:
$2 \times 33 + 1 \times 28 + 4 \times 12 + 8 \times 19 + 1 \times 8 = 302/800.$

d. Lagooning of Sludges

i. Process Description

Lagoons are a method of land disposal for sludges and usually the most economical solution to this problem.

Usually several lagoons are worked simultaneously side-by-side so that a lagoon can be partially filled (say to a depth of one foot) and then left to dry for some time before an additional layer of sludge is applied. Drying is caused by drainage (through previously laid pipes), evaporation, and transpiration. By means of these long-term drying processes, the wet sludge will lose 25 to 50 percent of its moisture content within two to three years. The drying will continue over a period of time, the rate depending upon climatic conditions in the area.

A flow diagram for a sludge lagoon is shown in Figure 30.

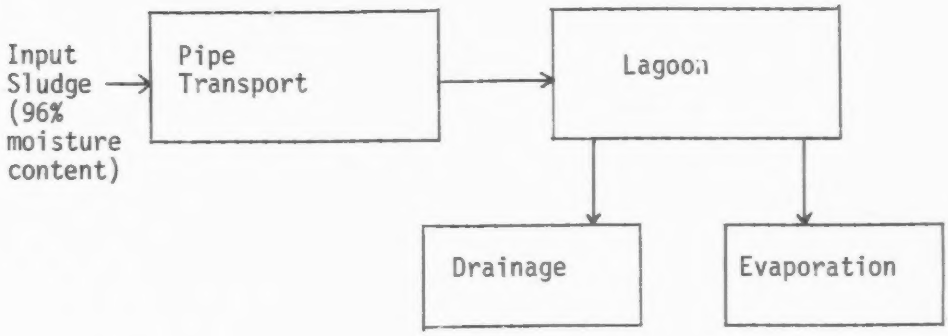
Lagooning costs average $0.70 per ton (of wet sludge). These costs are, however, very dependent on land costs and distance of the lagoons from the treatment plant.

Materials Balance

1 ton sludge ⟶ 160 lb sludge
(96% moisture content) (50% moisture content)

FIGURE 30

FLOW DIAGRAM FOR A SLUDGE LAGOON



ii. Evaluation

Net Costs. Although some portion of lagooned sludge may ultimately be used as soil conditioner, there is no market value for this product. Therefore net cost of lagooning = total cost = $0.70 per ton (at 96% moisture content).

Rating: 8/8.

Waste Reduction. Only the moisture content of the sludge is reduced. The entire solids content remains as a waste.

Rating: 1/8.

Flexibility. A large land area is required for this technology. In addition, drainage precautions need to be taken and a careful control of the aesthetics of the lagoon must be maintained.

Rating: 1/8.

State of Development. This is one of the most commonly used sludge disposal technologies in practice.

Rating: 8/8.

Conservation of Natural Resources. The only resource being recovered is a variable-composition soil conditioner for which there are inexpensive and plentiful substitutes. As a result only a very small fraction of lagooned sludge is ever used for this purpose, the rest remaining as waste.

Rating: 1/8.

Weighted Total:

$$8 \times 33 + 1 \times 28 + 1 \times 12 + 8 \times 19 + 1 \times 8 = 464/800.$$

C. SUMMARY OF SOLID WASTE PROCESSING COSTS

Tables 82 through 86 summarize the processing cost information included in this chapter. Capital, operating and total costs are given for the application of each technology to the appropriate waste streams. To arrive at a total cost per ton of waste treated, capital costs were annualized, prorated across the annual capacity and added to the operating costs. Parameters such as life span, interest rate and salvage value have been assumed to be those suggested by current equipment manufacturers, or were estimated as described in the appropriate sections of this chapter. The costs

TABLE 82

TOTAL COSTS OF MUNICIPAL WASTE TREATMENT TECHNOLOGIES
$/ton of Waste (25-30% moisture)

TECHNOLOGY	PLANT SCALE:		
	100 TPD	400 TPD	1000 TPD
1. Combustion Processes			
a. Combustion without resource recovery	19.00	7.80	4.50-6.00
b. Combustion to produce steam	21.50	10.50	8.20
c. Combustion to produce electricity from steam	26.00	13.50	10.20
d. Combustion to produce electricity from combustion gases		9.20	
e. High temperature combustion without resource recovery		10.00	
f. High temperature combustion to produce steam		12.00	
g. Combustion as a fossil fuel substitute		5.00	
2. Chemical Processes			
a. Pyrolysis without resource recovery		12.60	8.80
b. Pyrolysis with resource recovery	19.50	8.75	6.30
c. Hydrolysis and ethanol production		7.64-15.28	6.00-13.00
3. Biological Processes			
a. Composting	10.83-23.58	5.47-13.52	
b. Methane extraction		8.01-9.84	
c. Cultivation of yeast SCP		22.00-38.00	18.00-26.00
4. Mechanical Processes			
a. Wet fiber recovery		5.75	
b. Dry fiber recovery		6.30	
5. Land Disposal/Reclamation Techniques			
a. Landfilling unprocessed refuse	3.00-5.60	2.30-4.30	1.90-3.50
b. Landfilling shredded refuse	4.10-7.70	3.30-5.10	2.85-4.40
c. Landfilling baled refuse			3.30
D. Landfilling baled refuse (Japanese process)		11.00	

TABLE 83

OPERATING COSTS OF MUNICIPAL WASTE TREATMENT TECHNOLOGIES
$/ton of Waste (25-30% moisture)

TECHNOLOGY	PLANT SCALE:		
	100 TPD	400 TPD	1000 TPD
1. Combustion Processes			
a. Combustion without resource recovery		4.60	2.60
b. Combustion to produce steam	17.00	6.20	4.40
c. Combustion to produce electricity from steam	21.00	7.10	4.90
d. Combustion to produce electricity from combustion gases		4.20	
e. High temperature combustion without resource recovery		4.40	
f. High temperature combustion to produce steam		5.60	
g. Combustion as a fossil fuel substitute		1.20	
2. Chemical Processes			
a. Pyrolysis without resource recovery		8.50	5.80
b. Pyrolysis with resource recovery	14.00	5.75	4.10
c. Hydrolysis and ethanol production		6.60-8.80	5.90-7.90
3. Biological Processes			
a. Composting	6.79-17.28	3.67-9.93	
b. Methane extraction			
c. Cultivation of yeast SCP		15.50-22.00	13.00-18.50
4. Mechanical Processes			
a. Wet fiber recovery		2.05	
b. Dry fiber recovery		4.00	
5. Land Disposal/Reclamation Techniques			
a. Landfilling unprocessed refuse	2.50-4.60	1.55-3.60	1.20-2.75
b. Landfilling shredded refuse	3.30-7.00	2.30-4.60	2.10-2.75
c. Landfilling baled refuse			3.00
D. Landfilling baled refuse (Japanese process)		7.70	

TABLE 84

CAPITAL COSTS OF MUNICIPAL WASTE TREATMENT TECHNOLOGIES

$-day/ton of Waste (25-30% moisture)

TECHNOLOGY	PLANT SCALE:		
	100 TPD	400 TPD	1000 TPD
1. Combustion Processes			
a. Combustion without resource recovery		5,400	4,600
b. Combustion to produce steam	15,500	13,200	12,000
c. Combustion to produce electricity from steam	23,000	18,200	15,800
d. Combustion to produce electricity from combustion gases		17,000	
e. High temperature combustion without resource recovery		16,000	
f. High temperature combustion to produce steam		19,000	
g. Combustion as a fossil fuel substitute		7,500	
2. Chemical Processes			
a. Pyrolysis without resource recovery		20,000	15,000
b. Pyrolysis with resource recovery	19,700	10,000	7,500
c. Hydrolysis and ethanol production		11,000-14,000	8,300-10,800
3. Biological Processes			
a. Composting	13,000-20,000	5,800-10,800	
b. Methane extraction			
c. Cultivation of yeast SCP		20,000-23,000	14,000-17,000
4. Mechanical Processes			
a. Wet fiber recovery		15,000	
b. Dry fiber recovery		3,000	
5. Land Disposal/Reclamation Techniques			
a. Landfilling unprocessed refuse	3,500	1,700	820
b. Landfilling shredded refuse	7,400	3,300	1,400
c. Landfilling baled refuse			1,300
D. Landfilling baled refuse (Japanese process)		8,000	

TABLE 85

COSTS OF ANIMAL MANURE TREATMENT TECHNOLOGIES

TECHNOLOGY	PLANT SCALE:		
	50 TPD	100 TPD	400 TPD
Total Costs $/ton of Manure (85% moisture)			
1. Heat drying	3.00-6.00	3.00-6.00	1.70
2. Combustion without resource recovery	3.10	2.10	1.20
3. Composting		3.10-6.40	1.70-3.80
4. Methane extraction		1.80-2.30	1.80-2.30
5. Pyrolysis with resource recovery	2.50	2.00	1.10
6. Cultivation of SCP		9.00	9.00
Operating Costs $/ton of Manure (85% moisture)			
1. Heat drying	2.25-2.40	0.25-0.40	0.10
2. Combustion without resource recovery	0.16	0.11	
3. Composting		2.17	2.11
4. Methane extraction			
5. Pyrolysis with resource recovery		.19	.08
6. Cultivation of SCP			
Capital Costs $-day/ton of Manure (85% moisture)			
1. Heat drying	2,700-4,000	2,700-4,000	1,800
2. Combustion without resource recovery	7,600	4,900	2,700
3. Composting			
4. Methane extraction			
5. Pyrolysis with resource recovery		3,600	1,700
6. Cultivation of SCP			

TABLE 86

COSTS OF SEWAGE SLUDGE TREATMENT TECHNOLOGIES

	PLANT SCALE:		
	50 TPD	100 TPD	400 TPD
Total Costs $/ton Of Sludge (96% moisture)			
1. Heat drying			2.00
2. Air drying			1.10
3. Wet oxidation	3.90	2.70	1.25
4. Combustion without resource recovery	0.60-1.75	0.48-1.65	0.42-1.52
5. Composting		2.10-2.50	1.10-1.60
6. Lagooning			0.74
7. Spray irrigation			1.70
Operating Costs $/ton of Sludge (96% moisture)			
1. Heat drying			1.50
2. Air drying			
3. Wet oxidation	1.90	1.50	0.38-1.00
4. Combustion without resource recovery	0.51-1.60	0.44-1.50	0.41-1.20
5. Composting			
6. Lagooning			
7. Spray irrigation			
Capital Costs $-day/ton of Sludge (96% moisture)			
1. Heat drying			1,900
2. Air drying			
3. Wet oxidation	8,000	4,700	2,750
4. Combustion without resource recovery	410-1,250	245-820	127-380
5. Composting			
6. Lagooning			
7. Spray irrigation			

are given for several scale sizes, wherever these could be developed. The total processing costs do not reflect the net cost of applying these technologies as they do not include credits for recovered resources.

D. SUMMARY OF THE EVALUATION RATINGS

Quantitative assessments or rankings of solutions to problems involving many factors can be misleading insofar as they suggest that there is an "objective" and unbiased way of making choices. There is a natural assumption that because some numerical rating or ranking is possible, it is possible to reduce many independent and possible interacting factors to one number with precision. Such an assumption is unjustified. However, this does not mean that a numerical evaluation and ranking procedure is useless. By seeking criteria that attempt to measure the "essence" of the problem, by assigning values to a given technology for each criteria, by choosing weights for the criteria and arriving at one number for ranking purposes, the evaluator is forced to consider, in express terms and in detail, many factors that might otherwise be omitted, miscalculated, or buried in unrecognized subjective judgments. The final selection by such a method is still, in an important sense, subjective, but it is at the least informed and thoughtful subjectivity.

Tables 87, 88 and 89 respectively summarize the numerical evaluation scores given to technologies for treating municipal waste, animal feedlot waste and sewage sludge.

For the treatment of municipal waste, two energy recovery schemes received the highest ratings: pyrolysis to produce storable fuel, and combustion with coal as a power station fuel. Mechanical recovery of paper fibers was also rated highly.

For the treatment of animal manure, energy recovery through pyrolysis to produce storable fuel was again rated highly. Incineration without resource recovery followed pyrolysis with a rating higher than other resource recovery schemes because the latter were less efficient in terms of waste reduction and cost at managing the waste burden.

Destruction of sewage sludge by incineration or wet oxidation was rated highly because of the efficiency with which these processes handle the waste sludge problem. Spray irrigation was the most highly rated resource recovery technology for handling sewage sludge.

In general, biological extraction processes received low ratings because they left a large residual fraction, failed to produce a widely marketable product, or posed potential threats to the human food chain.

TABLE 87

Municipal Waste Technology Rating

	Technology	No Resource Recovery																No Resource Recovery			
Criterion	Weight	Combustion	High Temperature Combustion	High Temperature Combustion - Steam Recovery	Combustion - Steam Recovery	Combustion - Electricity Recovery from Steam	Combustion - Elec. Recovery from gases	Municipal Waste Power Station Fuel	Pyrolysis with resource extraction	Pyrolysis without resource extraction	Ethanol Production	Hydrolytic Glucose Production	Single Cell Protein -	Compost	Methane Production	Wet Fiber Recovery	Dry Fiber Recovery	Loose Landfill	Shredded Landfill	Baled Landfill	Landfilling High Density Bales
		Rating																			
1. Cost	33	4	2	4	4	4	4	8	8	2	4	4	1	4	4	8	8	8	8	8	2
2. Waste Reduction	28	8	8	8	8	8	8	8	8	8	1	1	1	1	1	8	8	1	1	1	1
3. Flexibility	12	8	8	4	4	4	4	4	8	8	1	2	1	4	2	4	4	4	4	4	4
4. State of Development	19	8	4	4	8	8	1	4	4	4	4	4	4	8	4	4	4	8	8	8	8
5. Conservation of Natural Resources	8	1	1	8	8	8	8	8	4	1	4	2	2	2	4	4	4	1	1	1	1
Weighted Total		612	470	544	620	620	487	676	692	470	280	276	165	376	292	644	644	500	500	500	302

TABLE 88

Animal Feedlot Manure Technology Rating

Technology		Incineration No Resource Recovery	Pyrolysis with Resource Extraction	Single Cell Protein	Compost	Methane Generation
Criteria	Weight	Rating				
1. Cost	33	4	8	2	2	4
2. Waste Reduction	28	8	8	4	1	4
3. Flexibility	12	8	8	8	8	2
4. State of Development	19	8	4	4	8	8
5. Conservation of Natural Resources	8	1	8	2	2	8
Weighted Total		612	724	366	358	484

TABLE 89

Sewage Sludge Technology Rating

Technology		No Resource Recovery						
		Incineration	Wet Oxidation	Lagooning	Air Drying - Drying Beds	Heat Drying	Composting	Spray Irrigation
Criterion	Weight	Rating						
1. Cost	33	8	8	8	8	4	8	4
2. Waste Reduction	28	8	8	1	1	1	1	8
3. Flexibility	12	8	8	1	2	4	4	2
4. State of Development	19	8	8	8	8	8	4	8
5. Conservation of Natural Resources	8	1	1	1	2	2	2	2
Weighted Total		744	744	464	484	376	432	548

It should be emphasized that these technologies were evaluated in terms of their large-scale application to solid waste management. Thus technologies that received low overall ratings may be very desirable if viewed in another context--for example, application on a small scale to very specific waste materials.

VI. IMPLEMENTATION STRATEGIES

A. STRATEGY CONSIDERATION

This chapter considers various strategies for improving solid waste management and selects a preferred strategy. The specific technologies for extracting resources from wastes were evaluated in Chapter V. The evaluation process applied to these technologies was carried out subject to the qualification that its conclusions were general and based in part upon estimates and projections of future developments. It nominated technologies for preferential treatment by the federal government with the expectation that other technologies would be valid where special local concentrations of wastes, or markets for waste products, made them so. It anticipated that other persons making evaluations of the same technologies, but under different projections of future developments, would also arrive at different results.

Because choice of technology may be affected by special situations, the strategy selection process has sought, to the degree possible, to develop implementation alternatives independent of any particular technology so that a change in technology need not vitiate a legislative and regulatory structure. In displaying the implementation alternatives, we have grouped them around six general approaches in order to emphasize the opportunities for cross-support among the different classes of governmental action that can be used to promote a chosen goal.

These approaches consist of five categories of end uses and a sixth category, waste reduction:

1. Use waste directly, or after conversion, as energy.
2. Convert waste into manufactured goods.
3. Convert waste into other salable commodities.
4. Use waste for soil beneficiation.
5. Use waste for landfill.
6. Reduce waste.

For each of these approaches, one or more sets of governmental actions has been identified consisting of programs that are internally consistent and mutually reinforcing. Some of these actions might be equally applicable to several end uses and we have displayed them where they seemed most appropriate. Although we carry out a selection process among the strategies under consideration, the process is much less rigorous among strategies than it is among technologies. The process of weighting and applying criteria is similar to that used in the selection among technologies, but its function is more to provide a check-list of considerations to be borne in mind while considering each possible government action than to furnish a rank-ordering among entire strategies.

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The seven strategies discussed below are intended as examples of possible combinations of incentive and disincentives. They do not make up an exhaustive list but they have been drawn to show the range of possible federal actions that would tend to increase the utilization of the technologies evaluated in Chapter V.

B. THE STRATEGIES CONSIDERED

1. Strategy A: Use Waste Directly for Energy

a. Proposed Government Actions

Regulation. Freight rates for hauling mixed municipal refuse should be made equal with those for hauling coal of an equivalent Btu content.

Tax. An excise tax would be imposed on fossil fuels consumed at stationary sources of production of electrical energy, calculated on the basis of Btu content, at the rate of $0.02 per million Btu or approximately $0.50 per ton of coal or equivalent. In 1969, electric utilities consumed 12,671 trillion Btu of energy from coal, petroleum and natural gas. Applied to that level of consumption, the proposed tax would yield $253 million per year.

Subsidy. To each power plant burning refuse mixed with fossil fuel, pay out of tax proceeds a subsidy of $0.20 per million Btu of municipal refuse burned or approximately $2.00 per ton of refuse. Payment in most cases could be in the form of a credit against the excise tax described in the preceding paragraph. If waste from all communities with populations of more than 145,000 were used in power plants, the subsidy would cost approximately $260 million per year.

Education. The public should be informed of the opportunity for waste utilization in energy production, that such utilization following metals separation will greatly reduce the volume of solid waste requiring landfilling and reduce the total cost of waste disposal, and that such utilization would provide utilities with a substantial reduction in overall fuel costs. The information program should also show that ferrous metal recovery from the mixed waste before use, necessary to prepare the waste for use in power plants, will help pay the costs of preparation.

Research and Development. The federal government should support completion of the existing St. Louis demonstration project and any subsequent grate modification or emission control development for which the St. Louis project demonstrates a need.

Federal Purchasing. U.S. government installations, including TVA facilities, utilizing fossil fuel for electric energy production should be modified to accept municipal refuse as part of their fuel when they are located near enough to municipalities, so that municipalities are willing to prepare their municipal wastes for such use by grinding, ferrous metal removal, and delivering it to the federal installation.

b. Discussion

Strategy A would be a partial strategy in that it would only affect those geographical areas with population concentration large enough to support local fossil fuel power plants. It would be disruptive of the existing market for power insofar as it taxed fuel for fossil fuel plants that were not located near enough to a municipality to make waste transportation to the plants feasible. Another aspect of disruption would be the transfer of a disposal cost from one activity to another, that is from household, industrial, and commercial waste generation to electric power consumption. Intergovernmental cooperation between the federal government and rate-fixing public utility commissions would be required to ensure that the utilities used municipal waste to reduce both excise tax and fuel costs rather than paying the tax and passing the added cost to consumers. The strategy would be somewhat limited in duration because of the anticipated increase in nuclear power production. That limitation, however, is not likely to be significant until after the year 2000. At present, fossil fuel plants supply 82.1 percent of our electrical energy and nuclear plants 0.9 percent. By 1985, nuclear plants are expected to provide 46 percent of electrical energy and fossil plants only 45.7 percent. In absolute amounts, however, by 1985 the fossil fuel plants will be consuming 19,934 trillion Btu of energy compared with their present consumption of 12,671 trillion Btu, so their capacity to absorb waste will continue to increase over the period covered by the study.

Apart from these limitations, Strategy A would provide a very strong market incentive to electric utilities to utilize 100 percent of the municipal waste outputs of the communities they served. If the optimum fuel mix projected for the St. Louis project proves correct, the proposed excise tax and subsidy would balance one another, creating an incentive for the utility to avoid the tax by burning waste. The subsidy would not remove a municipality's solid waste disposal costs but it would greatly reduce them. The preparation may be carried out by the municipality at its own cost or by the utility for a charge to the municipality. The net cost of fuel preparation to most municipalities should be below sanitary landfill costs. It is not yet clear whether increased costs of maintenance or emission control and the increase in ash disposal costs will be sufficiently high to approximate the price per ton of coal. If they are significantly lower, the cost of the process may be further reduced by payments by the utilities for the difference between the fuel value of the waste burned and these additional costs.

Strategy A need not stand alone. It might be put into effect in conjunction with one or more of the strategies suggested below.

2. Strategy B: Convert Waste into Fuel Oil

a. Proposed Government Actions

Regulation. None.

Taxation. Impose an excise tax of one-tenth of one percent on the price of all retail purchases, to yield an annual revenue of approximately $450 million by 1975.

Subsidy. Pay to any public or private entity undertaking to process waste, $0.0351 per gallon for each gallon of #6 fuel oil or equivalent produced from agricultural and municipal combustible waste.

Education. Inform the public that the increase in retail prices represents a transfer from municipal tax structure to federal tax structure, of a part of the cost of waste disposal, in order to permit a national program of resource recovery. Show that the results of such a program are to provide additional fuel for power production and to reduce per unit waste disposal costs by obtaining the maximum resource value from the wastes before disposal.

Research and Development. Continue and expand pyrolysis development programs until 500- to 2000-ton-per-day-capacity equipment is commercially available.

Federal Purchasing. Give preferential procurement treatment to #6 oil or equivalent produced from pyrolysis of wastes for use in federally owned or operated electric power plants, heating plants, and U.S. Navy ships.

b. Discussion

The subsidy of $0.0351 per gallon is the equivalent of $2.00 per 450 pounds of oil, the amount obtained from one ton of municipal refuse. The net effect of the strategy will be to add $2.00 to the existing $3.50 of credits per ton of municipal waste that can be expected from pyrolysis as against the $7 to $8 per ton costs of the process, so as to permit the municipality to dispose of its wastes for a cost of $1.50 to $2.00 per ton. The proposed excise tax on all retail sales would be too small to reduce demand for consumer goods. It is intended primarily to provide tax proceeds from which to pay the proposed subsidy. The cost of the subsidy is approximately $450 million a year and is calculated on the basis of paying $2.00 per ton for 227 million tons of waste per year. This figure represents the amounts of municipal wastes currently produced by cities of populations of more than 145,000 (the population that would generate enough waste to supply a 400-ton-per-day plant), which makes up 64 percent of the population, and the number of cattle on feedlots producing 100 wet tons per day of manure (which accounts for two-thirds of all cattle on feedlots). The sales tax is calculated on the basis of retail sales at the level of approximately $450 billion per year projected for 1975. Neither the tax nor the marketing of the oil produced from the waste will disrupt existing markets. Demand for low-sulphur #6 oil is strong and expected to become increasingly so. Legislation would be required to impose the tax and pay the subsidy. Although the subsidy would probably have considerable public support, the excise tax on sales, a federal sales tax, would be likely to encounter considerable legislative and popular opposition. Administratively, collection of the tax would not significantly alter existing tax collection administration. Disbursement of the subsidy would not be complex. Less than 1000 plants would be needed for the municipal waste, between 2000 and 3000 smaller plants for the animal waste. Each could submit monthly vouchers for tons of waste accepted for processing and gallons of oil produced. Verification could be carried out by occasional site visits to monitor intake and output, and by cross-checking with tax payments calculated on sales.

The strategy could be implemented in the very near future. It would require completion of current development work on pyrolysis, and passage of the implementing legislation.

Its effectiveness would be in part limited by the same considerations of long-term prospects for conversion from fossil to nuclear or fusion energy that affect Strategy A. It would, however, place the charge for waste disposal on the activity that directly or indirectly generates the wastes. It would reach a larger fraction of waste than Strategy A because of its ability to absorb agricultural waste. It would also furnish a resource, oil, that has the advantage of flexibility over municipal waste used as fuel. Oil can be used in more different applications than municipal waste. It can be transported using existing facilities and stored indefinitely. Subject to whatever qualifications may arise from the slight acidity of the pyrolysis product, it would sell in a market in which foreseeable demand is very strong. No further incentive would be necessary to encourage use of the product once produced.

3. Strategy C: Using Wastes as Raw Material for Manufacturing

a. Proposed Government Actions

Regulation. None.

Tax. An excise tax of 1 percent would be imposed on the sale of packaging materials and containers to manufacturers or packers of products, yielding approximately $250 million per year. A further excise tax of 5 percent would be imposed on all products incorporating previously pulped fibers derived from wood having a fiber content of less than 20 percent reclaimed fiber.

Subsidy. A subsidy of $2 per ton of municipal waste, costing approximately $260 million per year if waste from all communities of more than 145,000 population qualified for the subsidy, would be paid to each public or private organization accepting municipal waste for processing by wet or dry fiber recovery.

Education. None.

Research and Development. Existing research and development systems for sorting ferrous and nonferrous metals, glass, plastics and other organic material from paper fibers and for recovering paper fibers through both wet and dry separation systems, should be continued until 400- to 2000-ton-per-day-capacity equipment is commercially available.

Federal Purchasing. Government purchase of paper products would give preference, in a given procurement, in accordance with the percentage of reused fiber in competing products.

b. Discussion

In 1966 approximately $25 billion was spent on all packaging. The 1 percent tax is designed to raise in excess of $260 million or roughly $2 per ton of municipal refuse generated by communities of more than 145,000. The strategy would produce marked disruption in existing markets. A considerable amount of recycling of paper fiber takes place in the existing market structure, but at a declining rate. The paper industry drew about 35 percent of its total fiber needs from recovered fiber in 1946, about 21 percent during 1966, and is expected to obtain about 19 percent of its fiber from recycled sources by 1976. Approximately half of the fiber is from packaging, the remainder from nonpackage paper products. About 85 percent of the reused fiber is used in the manufacture of paperboard, only about 15 percent in paper. The proposed strategy, to the degree it was effective, would alter the appearance, and to some degree the performance of many paper products. It would also change their costs.

At present, approximately three-fourths of the paper industry is made up of integrated plants equipped to handle all phases of processing from log to finished product. They are located near timberland. These plants tend to be located near sources of virgin fiber rather than near markets, so that shipping costs need be paid only on the finished product rather than on the raw material. Compelling a manufacturer to use a proportion of reclaimed fiber would compel him to pay the transportation cost on the reclaimed fiber from urban area to plant. Costs would be even higher, so long as the majority of fiber in the product was virgin fiber, if the plant were to be located close to the urban market and reclaimed fiber source, but remote from the source of virgin fiber. Approximately one-fourth of the paper industry makes its products from reclaimed fibers, derived 16.6 percent from residential sources, 43.4 percent from commercial enterprises, and 39.8 percent from paper plant scrap (so-called conversion waste). These plants are equipped to clean and remove unwanted treatment chemicals from the scrap on which they depend. The present division of paper raw materials between virgin pulp and paper scrap is expected to change when the increasing demand for paper products outruns the possible output of acreage available for growing pulpwood during the 1980's. Both traditional sources of recovered paper fiber (plant scrap and commercial waste, including separately collectable materials like newspaper) and the wet and dry fiber extraction processes now under development may be expected to provide fiber to meet the demand, at higher prices than today's. The effect of the proposed strategy would be to accelerate this anticipated market development.

The legislation necessary to impose the strategy could be expected to meet opposition grounded on antipathy to governmental standards that would degrade product specifications. Public acceptance would depend to a large degree on the appearance and performance of the products produced to the required specifications. Administratively, the strategy would call for monitoring raw material consumption and product composition at a relatively small number of facilities. In 1969, in the United States, there were 323 pulp mills, 468 paper mills and 386 paperboard mills. The strategy would require a brief delay long enough to permit integrated pulp manufacturers to finance and construct paper scrap processing equipment and construction of municipal fiber recovery plants.

The strategy would be only partially effective as a means of dealing with combustible waste. It would deal with only a portion of the combustible content of municipal wastes which are in turn only a portion of the combustible waste stream. Its duration as an influence on waste disposal and resource recovery would be limited by the market factors that will tend to produce a similar result during the 1980's and 1990's even if Strategy C were not put into effect.

4. Strategy D: Treating Wastes for Soil Beneficiation

a. Proposed Government Actions

Regulation. Reduction in freight rates for compost (or ground municipal waste if current research proves it equal to compost in soil beneficiation) to the lowest rates charged for transportation of bulk material.

Tax. An excise tax would be imposed on all retail sales of one percent so as to yield an annual revenue of $4 billion.

Subsidy. A payment of $20 per ton would be made to each person utilizing mixed municipal refuse after composting (or grinding) for soil beneficiation. The proceeds from the proposed tax would be sufficient to provide incentive for distributing 200 million tons of waste out of the 220 million generated by communities of 145,000 or more and cattle feedlots producing 100 tons of wet manure per day.

Education. Public resistance to the proposed tax could be offset by an education program showing the foreseeable need for increased agricultural productivity, and the rate of withdrawal of agricultural land from food production in areas with sufficient rainfall for crop production, caused by strip mining and expanding urbanization. Against this background, massive composting would offer a promising opportunity for reclamation of land.

Research and Development. Composting is a long-established technology but some of its costs could be reduced by improvement in pre-composting sorting to remove metals and plastics. Further federal support for research and development in refuse sorting would be a part of this strategy.

Federal Purchasing. None.

b. Discussion

In the long term, increasing soil productivity and expanding agricultural land will become a matter of very high national priority. It is clear that it is presently not in that category. Composting as a form of solid waste disposal is an acceptable technology from an environmental viewpoint, but has only very slight promise of returning a credit from sales of the resource recovered. Considered as a form of sanitary landfill, composting would still require the payment of transportation and of spreading costs.

The strategy would not disrupt existing markets. Enactment of the tax and subsidy provisions would encounter opposition based on the high subsidy cost but would not raise new institutional objections. Portions of the public would be likely to favor the strategy since the resource would be recovered without the generation of environmentally objectionable byproducts. Its utilization, while expensive, would be in a mode that would hold promise of long-range benefit.

Administration will require verification that the compost is in fact being spread for soil beneficiation uses, not merely deposited into landfill sites. The distinction will be important if the strategy is to do anything more than transfer landfilling costs to the federal government, upgrade the quality of landfilling, and provide a large profit to the operator. Making a distinction between landfill and soil beneficiation will require the promulgation of regulations and a continuing verification system.

The strategy could be put into effect immediately and could be used indefinitely. It would be applicable to all forms of combustible wastes except plastics.

5. Strategy E: Sanitary Landfill for Recreational Development

a. Proposed Government Actions

Regulation. None.

Tax. None.

Subsidy. None.

Education. A public information program coupled with training programs for regional planners, land developers, municipal sanitary engineers, and zoning boards, should be employed to alter the emphasis on disposal governing current landfill site selection to one emphasizing recreational resource recovery.

Federal Purchasing. None.

b. Discussion

This strategy is one that may be coupled with one or more of the others. It is compatible with several of them.

Many communities have used, or are planning to use, sanitary landfills for golf courses, playgrounds, parks, and ski-hills. The process of regional planning, however, has not systematically considered the building of recreational facilities from otherwise unusable land. Where cities are large or spreading rapidly, acquisition costs militate in favor of remote landfill sites, the distance to which will, in turn, raise operating costs. The cost of more expensive land closer to the metropolitan area could be offset by revenues from subsequent recreational uses. The most promising areas for implementation of the strategy would be in those parts of the United States where winter temperatures are low enough to permit a skiing season of several months' duration with or without man-made snow. Such a use would permit a single site to function as a disposal point for an extended period with the expectation of a recreational demand sufficient to motivate users to travel the distance to the site. Ski-hills are the best large-scale recreational resource opportunities; where land costs are lower, however, multiple golf courses, at intermediate distances from the city, are more conventional opportunities.

The strategy would not require legislation, would meet public acceptance, create no new administrative burden, and could be carried out at the present time.

As a form of resource recovery, its benefits are marginal. Other than in the ski-hill example, the significant recreational resource is not the fill but is the open space that can in most cases be utilized as parkland or golf course without the addition of municipal waste or incinerator residue. The ski-hill, while it would offer a long-term disposal site and then become a recreational resource not otherwise available, would be feasible for only that portion of the country without competing natural ski-hills and with sufficient cold weather to sustain a ski season of several months.

6. Strategy F: Waste Reduction

a. Proposed Government Action

Regulation. (a) Impose a size limitation on newspapers and magazines. (b) Prepare regulations defining specifications for automobile tires that would tend to promote long wear.

Tax. (a) Impose an excise tax of 20 percent on all disposables for which there is a non-disposable alternative, e.g., paper towels, plates, diapers. (b) Impose an additional excise tax of 30 percent on automobile tires not meeting specifications for long-wearing tires. (c) Impose a "value-subtracted" tax on all manufacturing processes pursuant to which the weight of a manufacturer's output of combustible solid wastes would be taxed. In some industries, wastes could be weighed and tax paid on the recorded weight. In others, especially those not employing combustion processing, the weight of products and byproducts could be subtracted from the weight of raw materials and the difference taxed.

Subsidy. None.

Research and Development. Undertake new lines of federally supported research and development (a) to reduce either the need for, or volume of, packaging; (b) to facilitate the development of multi-channel cable television and associated electronics equipment so as to permit visual scanning and data retrieval equipment to replace written records for portions of the information exchange that is now communicated as written material.

Education. Undertake a public information program indicating the proportion of waste that consists of disposables and packaging. The public would be given an indication of the extent to which collection costs and the associated local taxes would be reduced by eliminating grocery bags, superfluous wrapping, disposables, and the like.

Federal Purchasing. Federal installations would be directed to substitute reusables for disposable products. Federal procurement and record keeping would convert, to the degree possible, to electronic recording and display of data in place of disseminating of paper records.

b. Discussion

In the event that an energy recovery strategy were selected as the appropriate form of resource recovery, this strategy would be at odds with it. If energy recovery were to be encouraged, it would be desirable to increase the paper and plastic content of waste by encouraging the consumption and disposal of paper and plastic, rather than decreasing it.

Strategy F would be very disruptive of present markets. The limitation on newspapers and magazines may be offensive to the First Amendment. Similar limitations applied to consumption of other products not shielded by Constitutional protection would also be unlikely. The legislation required would encounter greater opposition than that required for most of the other strategies because the impact of the legislation would increase the cost of living and alter living patterns. Congressional opposition would result from consumer unwillingness to forego the convenience of disposable products and manufacturers' opposition to the abolition of existing markets. While portions of the public would be willing to put up with inconvenience for the sake of significant abatement of environmental deterioration, the public as a whole would be skeptical of claims that doing without combustible disposables would make a measurable difference in the costs of municipal waste collection and disposal.

The taxes on disposables and on tires would not materially increase existing demands on the Internal Revenue Service; the value-subtracted tax would create new burdens. For those manufacturing processes in which it is impractical to keep or audit accurate records of solid waste output, the materials balance alternative is likely to be more difficult than it at first appears. Many processes give off carbon dioxide, water vapor, or nitrogen that cannot properly be classed as wastes. In consequence, a materials balance computation would not be a simple matter of subtracting the weight of salable products from weight of raw materials. Process-by-process waste production generation data would be required in which the amounts of "free" emissions (water, free nitrogen, and carbon dioxide) were determined so that the difference between input and output could be reduced by the amount of free emissions. Even without the complex data analysis that the process would require, it would impose new record-keeping demands on the many manufacturers who do not presently buy or sell by weight but by some other unit of measurement.

The strategy could be put into effect immediately but would have only marginal effect on the reduction of wastes. It would not affect the generation of animal manure and would reduce only the part of the weight and volume of mixed municipal waste represented by newspapers and disposable combustible products. To the degree it succeeded, it would reduce the opportunities to extract energy or other usable resource from the combustible component of mixed municipal waste. Public opposition would limit its long-term success.

7. Strategy G: Improved Disposal and Increased Resource Recovery through Revenue Sharing

a. Proposed Government Action

Regulation. ICC would reduce freight charges for transportation of unprocessed or processed waste to the lowest rates for comparable or competing materials.

EPA would promulgate a list of approved disposal, and of approved resource recovery, technologies. Approved "disposal" technologies would be those from which no beneficial end-product was generated, e.g., sanitary landfill where no recreational after-use was made of filled sites, incineration without recovery and sale of energy or residue separation, etc., but in which the use resulted in no adverse environmental effects. "Resource recovery" technologies would be those from which either a product would be marketed or a non-marketable product was produced under circumstances in which it was used for the public benefit. Energy and paper fiber recovery would be approved resource recovery technologies; so would composting of wastes (provided that the compost product was spread on land for genuine soil reclamation purposes).

EPA would promulgate standards for each industrial and agricultural activity, requiring that combustible wastes be managed through approved disposal or resource recovery technologies.

Tax. Impose a tax of one-tenth of one percent on all retail sales to yield annual proceeds of approximately $400 million increasing at a faster rate than population growth. Proceeds of the tax would be paid by the federal government to state waste management authorities in each state against vouchers covering subsidies earned in that state.

Subsidy. The state waste management authority will pay a subsidy of $2 per capita to any municipality that, through its own facilities or through those of private contractors, processes all its waste through an approved resource recovery technology; a subsidy of $1 per capita would be paid to municipalities disposing of their waste through an approved disposal technology.

Research and Development. None.

Education. Undertake an information program to indicate to municipalities and to the private sector the opportunities the proposed payments would offer, both for partially transferring waste disposal costs from the municipal to the federal government, and, in the locations where one or another resource recovery opportunity was already near a break-even point, for profit making. Inform the public of the purpose of the tax and of the opportunities for increased resource recovery and improved disposal that it makes possible.

Federal Purchasing. The federal government would give preferential procurement treatment to materials derived from or used as recovered resources including wastes made available for use as fuel in power production.

b. Discussion

Strategy G would produce some perturbation of the materials markets by making available secondary materials in greater amounts at prices competitive with virgin materials. It would not, however, directly alter the existing market for consumer products. For this reason, and because the strategy would require the creation of state agencies for its administration, rather than the enlargement of the federal government, it would be likely to be sympathetically reviewed by Congress. (The action it proposes might as easily be taken by individual states without federal participation but for the fact that if a single state paid a subsidy there would be a strong incentive for its subsidy system to draw wastes from outside the state in sufficient quantities to exhaust the funds generated from retail sales within the state.) State legislatures would be likely to support the program since it would partially transfer the costs of municipal waste disposal to federal revenues while giving state government credit for the administration of the subsidy program. The public would support Strategy G because it would not sharply increase consumer prices and would not affect consumer purchasing patterns, but would produce a substantial increase in the recovery of resources from wastes.

In terms of administrative costs and complexity, the taxing facet of the strategy will not change existing procedures significantly. The rule-making necessary to define approved resource recovery technologies and approved disposal technologies should be a relatively brief effort for EPA. A rule-revision process to accommodate change in technology would be compatible with existing administrative procedures. The disbursement function to be carried out by state governments would also not impose significant burdens. A verification process would be necessary for two functions. It would determine in advance that a proposed resource recovery project was, in fact, to be used for resource recovery and that its products would not subsequently be dumped or abandoned. It would determine by spot checks and monitoring that applicants for the subsidy were in fact carrying out the processing for which they claimed credit.

The strategy could be implemented promptly. It would be likely to attract into resource recovery all wastes from which values can reasonably be recovered. Because the amount of the resource recovery subsidy is less than the cost of resource recovery processing, the subsidy will not be an incentive to produce goods for which there will be no market. It will encourage processing that would otherwise be marginally uneconomical only where a substantial market for the resulting product exists.

It has a side benefit. It would make research and development in the resource recovery area more promising for private capital so that governmental support for such work can be reduced.

This strategy affects all major waste streams. In doing so, however, it utilizes federal subsidies only to reduce the costs of a function that would be paid for by the general population through local government in the absence of the incentive strategy. It does not utilize federal revenues to reduce operating costs of agricultural or industrial waste management so that the products of these economic activities will bear the whole cost of the waste management efforts associated with them. To do otherwise would be to remove the cost incentives that tend to discourage such waste-producing activities or products.

By utilizing per capita payments to municipalities in place of subsidies calculated according to weight of waste processed, it avoids the administrative complexity and costs associated with verifying the weight of wastes being processed.

C. STRATEGY SELECTION

1. Criteria

Persons participating in implementation strategy selection were required to assign weights to the following criteria as a first step in the selection of a preferred strategy.

Technological Promise. Some strategies rely on fully developed technologies, but most anticipate utilization of technologies that are at a preliminary stage of development. This criterion is intended to measure the degree of certainty with which it can be assumed that a given technology will prove technologically feasible.

Proportion of Waste Stream Affected. Some strategies will affect only a small portion of the total waste stream; especially where some components of the strategy place significant restraints or costs on the public, it is desirable to consider what degree of change the strategy can bring about to the entire solid waste problem.

Disruption of Existing Production or Market Structure. Some waste reduction or resource recovery strategies would impose, directly or indirectly, marked changes in the existing markets for primary or secondary materials and in the operations of producers. This criterion was designed to reflect the significance of these effects.

Legislative Opposition. Some strategies would require new legislative or administrative restructuring of governmental responsibility in which competing political values would be a potential obstacle to implementation. This criterion was intended to be a value that reflected both the probability that new legislation or inter-governmental cooperation of like sensitivity would be required and the probable degree of opposition to it.

Public Acceptance. The public would be involved in strategy implementation in many ways. Systems requiring pre-collection sorting and cleaning of household wastes would need universal public participation, container taxes would be paid by the public, purchasing patterns giving preference to goals utilizing recycled materials would affect market prices for secondary materials. This criterion did not purport to measure the degree of public participation but the extent to which the required degree would meet with public approval.

Administrative Costs and Complexity. The costs to be compared using this criterion were those to the government that would arise from staffing and operating whatever regulatory, enforcement, or administrative organization would be required by a given strategy. Administrative costs and complexity were dealt with in a single criterion because they would correlate closely and because it might be possible to make qualitative judgments about complexity that would be more reliable than quantitative estimates of administrative costs.

Time Required to Accomplish Strategy. Some strategies would require very long delays before implementation, some would be carried out immediately. The relative importance of the attribute of immediate feasibility must be established as an expressed value in the selection process.

2. Application of Criteria

The procedure followed in assigning weights to criteria for evaluating strategies was similar to that described in Chapter V. The weights arrived at were:

Technological Promise	12
Proportion of Waste Stream Affected	18
Market Disruption	13
Legislative Opposition	15
Public Acceptance	21
Administrative Costs and Complexity	11
Time Required to Accomplish	10

Each strategy was then rated in terms of these criteria along the same logarithmic scale used in the earlier evaluation.

Several of the criteria were given an additional value for selection purposes. Technological Promise, Proportion of Waste Stream Affected, and Legislative Opposition were each treated as rejection categories in which the lowest possible score would serve as an absolute bar to a strategy. The assumption underlying this decision was that a technology that would not work, a strategy that affected only an insignificant fraction of the waste stream, or a legislative proposal that could not be enacted would not be implemented regardless of how high its score might be with respect to other categories. In practice, of these criteria, only Legislative Opposition was awarded the lowest possible score with respect to Strategies D and F. In each case the strategy affected was one that already had a relatively low score.

In this rating the following values were used. The results of the rating are given in Table 90.

Technological Promise:

Very promising	8
Some promise	4
Significant problems	2
Severe problems	1

Proportion of Waste Stream Affected:

All major streams	8
Most of a major stream	4
A small portion of a major stream or all of a minor stream	2
A small portion of a minor stream	1

Market Disruption:

None	8
Slight	4
Substantial	2
Severe	1

Legislative Opposition:

None	8
Slight	4
Substantial	2
Severe	1

Public Acceptance:

Very popular	8
Some popularity	4
Slight opposition	2
Severe opposition	1

Administrative Costs and Complexity:

No costs, simple	8
Slight cost and complexity	4
Considerable cost and complexity	2
Heavy costs, severe complexity	1

Time Required:

Up to 5 years	8
5 to 10 years	4
10 to 20 years	2
More than 20 years	1

TABLE 90

STRATEGY RATING

Criterion	Weight	Strategy A	B	C	D	E	F	G
Technological Promise	12	8	8	8	8	8	8	8
Proportion of Waste Stream Affected	18	4	8	2	2	2	2	8
Market Disruption	13	2	8	1	8	8	1	8
Legislative Opposition	15	4	4	2	1	8	1	8
Public Acceptance	21	8	8	4	1	4	2	8
Administrative Costs and Complexity	11	8	8	4	2	4	1	8
Time Required	10	8	8	4	8	8	8	8
Total Weighted Score		590	740	343	(374)[a]	524	(275)[a]	800

[a] Totals in parentheses indicate disqualifying score in a rejection category.

3. Strategy Selected

Strategy G was selected. It provides for regulation of agricultural and industrial waste management by imposition of federal management standards, imposing a one-tenth of one percent excise tax on the sale of goods to provide funds for a revenue-sharing plan, and, from these funds, paying a subsidy of $1 per capita per year to municipalities processing all waste through approved waste disposal systems, and $2 per capita per year to municipalities processing all waste through approved resource recovery systems.

VII. RESEARCH AND DEVELOPMENT NEEDS

A. INTRODUCTION

Research is described below, by waste stream, according to the functional need it would fill. A concluding summary groups the identified research needs according to their relative priority.

B. MIXED MUNICIPAL WASTE

1. Unsorted Wastes

Two technologies were identified as the most promising for extracting resource value from mixed municipal waste after preliminary removal of ferrous metals: pyrolysis to produce a petroleum substitute and utilization of wastes as a supplemental fuel for coal-burning electric power generating plants. Development of both technologies is being supported currently by EPA on a pilot plant scale. The current development phase may be expected to identify a number of problems relating to waste storage, feed mechanisms, temperature control, emission control, and residue management not foreseeable at the beginning of the pilot plant stage. Research directed to solving these problems as they are identified should be fully funded.

2. Sorting Municipal Waste

Paper. Separation of paper fiber from mixed waste is currently feasible through a wet separation process. A dry separation process is still in the planning stage. Both processes should be investigated further with particular attention to potential opportunities for lower energy demands and costs.

Plastics. At the present time, plastics sorting technology is in the planning and laboratory testing stage, both for separating the plastic fraction as a whole from municipal waste and for separating mixed plastics by type and color. The opportunities for fabricating marketable products from plastics waste are increased in proportion to the homogeneity of the waste. Plastics are now a small fraction of mixed municipal waste, between 2 and 3 percent. They are increasing at the rate of 12 percent per year and are expected to increase to 4 percent by 1980, to 6 or 7 percent by 1990. Plastics separation processes should be investigated at a level of support commensurate with the expectation that plastics will not become a sufficiently large fraction of the waste stream for separation to merit serious consideration until 1990.

3. Materials Sorted from Municipal Waste

This study sought to identify a number of alternative government actions that might affect solid waste management and to assess their relative merits. Because of the very large number of technologies and alternative actions discussed, corporative evaluation of each was for the most part qualitative, even though based in part on quantitative cost and performance data.

The economic impact of alternative incentive and disincentive programs on markets for recovered resources will require much more sophisticated and detailed economic research before implementation. The evaluation process described in this report should be carried forward by developing a methodology for forecasting the complete economic impact of a given incentive, disincentive, or combination of measures on raw material markets, process and product substitution, and employment, nationally and regionally, and by utilizing such a methodology to prepare quantitative estimates of such impacts.

4. Disposal of Municipal Wastes

Continuation of current research on air pollution emission and ground and surface water leachate problems related to setting standards for incinerator and sanitary landfill design and operation is necessary. A new economic and institutional research effort should be undertaken to determine the most appropriate areas, forms, and powers for interstate regional solid waste management planning agencies.

C. AGRICULTURAL WASTES

1. Resource Recovery

The most promising technology for resource recovery from animal feedlot wastes is pyrolysis to recover a salable petroleum substitute. Research into systems for dewatering animal wastes and otherwise augmenting the efficiency of pyrolysis applied to animal wastes should be given very high priority.

2. Disposal

Incineration of feedlot wastes is the preferred disposal technology but further development is needed to reduce the costs of drying and to improve the emission controls on feedlot waste incinerators.

D. SEWAGE SLUDGE

1. Resource Recovery

EPA is currently supporting economic studies and pilot plant demonstrations of spray irrigation of sewage sludge. The principal technological question to which a definitive answer is being sought is whether spray irrigation of sewage sludge can have a long-term adverse effect on ground water quality. At the completion of these projects there would not appear to be a need for further research since this technology appears to be at a sufficiently advanced state of development for wide-scale use.

2. Disposal

Sewage sludge incineration, although also at an advanced state of development, requires further research to reduce the extent to which slurry dewatering is necessary before combustion and to improve ash handling characteristics.

E. SOURCE REDUCTION

A research program to determine the effects of user charges on reduced consumer acceptance of excessive packaging and on litter generation resulting from clandestine disposal to avoid user charges should be carried out.

F. PRIORITIES

Mixed municipal waste research should continue to hold the highest research priority over the near future. This is because waste management costs in this area are already high and growing rapidly. This waste stream also has the greatest immediate impact (in terms of nuisance, aesthetics, health, etc., as well as cost) on the general population and effective methods for dealing with this waste flow cannot be delayed.

Animal waste research should receive increasingly greater priority over the next five years because of the projected increases in amounts and concentrations of animal waste and the impact on animal waste disposal of effective water pollution control enforcement.

Research and development connected with recycling industrial CSW is placed at a low priority because:

(1) Individual industrial CSW streams are small in size and differ significantly in composition. Heterogeneity in

small quantities of material does not lend itself to economical separation/recycling techniques.

(2) Industry already has an existing profit incentive to reduce its waste generation.

(3) Industry already has, or can develop relatively easily, markets for byproducts that would ordinarily be considered wastes.

(4) Industry (as compared to agricultural or municipal waste generators) has control over many of the elements that could make resource recovery of its own wastes economically viable.

The following priorities are intended to suggest both relative priority in allocation of research and development resources and in the urgency of undertaking the research categories described.

First priority:

Pyrolysis and utilization of mixed municipal wastes as supplemental fuel for coal-burning power plants.

Methodology to determine economic impact of incentive and disincentive measures.

Second priority:

Sorting of municipal wastes.

Pyrolysis and incineration of animal wastes.

Standard-setting related to waste disposal technologies.

Pyrolysis and incineration of sewage sludge.

Third priority:

Separation of plastics by type and color.

Institutional opportunities for required sanitary landfill planning.

Effects of user charges on waste generation and litter.

APPENDIX A

COMPUTER MODEL AND METHODOLOGY FOR COMBUSTIBLE MATERIALS FLOWS, PROJECTIONS, AND WASTE GENERATION

Table 91, "Combustible Materials Transactions (Raw Data/Base year = 1967)," constitutes the raw data base for the combustible materials flow analysis. Because of its bulk, Table 91 is not reproduced here. A copy may be viewed at the Solid Waste Division of the National Environmental Research Center, 5555 Ridge Avenue, Cincinnati, Ohio. The basic methodology used to generate Table 91 is given in Chapter III. Some further explanation is needed, however, to describe the formal display of the information in Table 91.

Since the vast majority of detailed materials-transacted information came from the *Census of Manufactures* everything built onto the basic *Census of Manufactures* data was put in an equivalent format: Buyer and Seller SIC code sector numbers (and associated Almon code numbers), dollar value, and weight of product transacted.

A sector, Mother Earth, was devised to be the seller of produce and lumber to the Agriculture sectors. Mother Earth was assigned SIC code 0001, Almon Code 900, and the product code was the same as when the produce was transacted from agriculture to a manufacturing sector, e.g., 12251 was the product code of fresh peaches from Mother Earth (SIC 0001) to Fruits and Nuts (SIC 0122) and from Fruits and Nuts to Canned and Frozen Fruits and Vegetables (SIC 2037).

In a few cases, Almon sectors were reorganized as to which SIC four-digit codes would be contained within each. This was done in order to reduce errors introduced by aggregation, and to more accurately predict influences and sector growth rates.

All of the combustible materials listed in the Census are not included. Some were excluded because of size -- the usual requirement was a weight of more than 0.5 million pounds, although there are several listings smaller than the minimum. A small quantity of those materials which were already in final manufactured product form have been excluded, all of which are paper or paperboard products and would no longer generate process waste in the buyer's sector.

All the transactions are grouped by buyer, and sorted in ascending order of SIC four-digit code buying sector. The name of buyer, with both his SIC code and the appropriate Clopper Almon code, is given on the top of the first page of that buyer's list of purchases. (Table 92 is a cross index between SIC codes and modified Almon codes as used here). Below each buyer, in ascending order of product code number of material purchased and sorted by product seller, are listed his combustible materials consumed. Only in a few cases does a buyer's list require more than one page, in which case, the second page follows without a heading.

Immediately below the buyer's identification is the list of column headings:

PRØD DOLLARS AMT MEAS WEIGHT W/C WASTE H/C BTU, K

The next line introduces the first seller, below which are listed his sales, and important information concerning the transaction is formatted in the field described above.

PROD	is the product code number. The name is listed in the attached product code dictionary (Table 93).
DOLLARS	is the buyer's price for the materials purchased, in Millions of dollars. In cases where Mother Earth (SIC 0001, CA 900) is the seller, the attached dollar value is zero.
AMT	are the amounts given in units MEAS, identified in Table 94.
MEAS	A table converting various MEAS to pounds is attached (Table 95) ordered by product code.
WEIGHT	is the weight of the material transferred given in millions of pounds (MEAS = LLB) except in cases of sales from Mother Earth in which it is amount produced: crops, manure, timber.
W/C	is the waste coefficient, dry weight of unused residuals divided gross weight of input (except in cases of sales from Mother Earth, in which case the W/C is defined as unused residuals divided by product gross weight (see Chapter III).
WASTE	Dry weight unused residual, = weight x W/C in all cases. Units are million lbs.
H/C	Heat coefficient, in thousands of BTU/lb (dry). Because of the broad range of materials, and the uncertainty in exact waste material composition, heat coefficients were divided into three broad groups:

500 < x	<8500, called	7500
8500<	<11500	10000
11500	<15000	12500

waste from products falling into each category are given in Table 96.

BTU,K	Product of the heat coefficient and the total amount of waste.

After the last product sold by a given seller to each buyer, the tranactions from seller to buyer are subtotalled, giving DOLLARS, WEIGHT transferred, weight of WASTE generated at the buyer from the material, and the BTU content of that waste.

After the last sequential seller from which a buyer buys, the subtotals are totalled.

This list proceeds on to the next sequential buyer.

ALMON-SIC CODE LIST

Table 92 is the cross index relating SIC economic sector codes and their equivalent Almon codes (modified in the manner described above). Each Almo Code which has been reorganized is denoted by an asterisk. Sectors which were not involved in our tabulation and model explicitly are not included.

PRODUCT CODE LIST

Table 93 lists product code number and product name for all combustible materials whose flows were traced through agricultural, construction, and manufacturers sectors. As described in the description of the Methodology Used in Research Task #2, the combustible materials product list was drawn primarily from the *Census of Manufacturers*, with help from *Agricultural Statistics -- 1969*. In some cases, where *Census* data was weak, overly aggregated or incomplete, Clopper Almon's Input-Output Model for base year 1967 was used to generate additional listings in order to bring the intersectional combustible materials transaction level into accord with the best information available. New transactions added for this reason are denoted by an "(F)" following the product name.

MEASURES DICTIONARY

Under the heading MEAS is the notation describing the units in which the product was measured in the raw data. The first letter will typically be a coefficient, the remainder will describe the units, e.g.:

LLB = L LB = million pounds

MSTN = M STN = thousand short tons of 2000 lbs each

CONVERSION FACTORS

Table 95 lists the conversion factors which were used to convert units listed under MEAS into pounds, so that all materials transactions could be viewed on a uniform basis. All materials which

TABLE 92

ALMON-SIC CROSS INDEX

p= part

ALMON CODE-NAME	SIC CODES
1 - DAIRY FARM PRODUCTS	0132
2 - POULTRY & EGGS	0133-0134
3 - MEAT,MISC LVSTK PRD*	0135-0136 p 0139 (not wool), 0193
4 - COTTON	0112
5 - GRAINS	p 0113, p 0119 (not sugar)
6 - TOBACCO	0114
7 - FRUIT & VEG	p 0119 (sugar), 012x,0192
8 - FRSTRY & FSHRY PRODS	074X, 081X-082X, 084X, 086X, 091X
9 - WHLSL TRADE WASTE*	
11 - WOOL SOURCE*	p. 139
12 - WOOL PROCESSORS*	2297
19 - MAINTNC & RPR CONSTR	p 15XX, p16XX, p17XX
20 - CMPLETE GUIDED MSSLS	
23 - MEAT PRODUCTS	201X
24 - DIARY PRODUCTS	202X
25 - CNND & FRZN FOODS	203X
26 - GRAIN MILL PRODUCTS	204X
27 - BAKERY PRODUCTS	205X
28 - SUGAR	206X
29 - CNFCTIONRY PRODUCTS	207X
30 - ALCOHOLIC BEVERAGES	2082-2085
31 - SFT DRNKS & FLVRNGS	2086-2087
32 - FATS & OILS	2091,2094,2096
33 - MISC FOOD PRODUCTS	2095,2097,2099
34 - TOBACCO PRODUCTS	21XX
35 - BROAD & NARROW FBRCS	221X-224X,226X, 228X
36 - FLOOR COVERINGS	227X
37 - MISC TEXTILES*	2291,2292,2294,2295,2298,2299,2394,2395,2397
38 - KNITTING	225X
39 - APPAREL	231X-238X

p= part

ALMON CODE-NAME	SIC CODES
40 - HOUSEHOLD TEXTILES*	2391-2393,2396,2399,2293,2296
41 - LMBR & WOOD PRODUCTS	241X-242X
42 - VENEER & PYLWOOD	2432
43 - MILLWORK & WOOD PROD	2431,2433,249X
44 - WOODEN CONTAINERS	244X
45 - HOUSEHOLD FURNITURE	251X
46 - OTHER FURNITURE	252X-259X
47 - PULP MILLS	2611
48 - PAPER & PPRBRD MILLS	2621,2631
49 - PAPER PROD, NEC	2641-2643,2645-2649
50 - WALL & BLDG PAPER	2644,2661
51 - PPRBCARD CONTAINERS	265X
52 - NEWSPAPER	2711
53 - BKS,PRDCLS,&MSC PUBS	272X-274X
54 - OTR PRNTNG SERVICES	275X-279X
55 - INDUSTRIAL CHEMICALS	281X
61 - MISC CHEM PRODS	2861,289X
62 - PLSTC MATRLS & RESNS	2821
63 - SYNTHERIC RUBBER	2822
64 - CELLULOSIC FIBERS	2823
65 - NON-CELLULOSIC FBRS	2824
66 - DRUGS	283X
67 - CLNNG & TOILET PREPS	284X
68 - PAINTS	2851
69 - PET RFNG & RLTD PRDS	291X,299X
71 - PAVING & ASPHALT	295X
72 - TIRES & INNER TUBES	3011
73 - RUBBER PRODUCTS	302X-3069
74 - MISC PLSTC PRODS	3079
75 - LTHR TAN & INDS LTHR	3111-3121
76 - LEATHER FOOTWEAR	3131-3142
77 - OTR LEATHER PRODUCTS	3151,3161,3171X,3199
78 - GLASS	3211,3221,3229,3231
81 - CMNT,CNCRT, & GYP SUM	3241,3271-3275
82 - OTR STONE&CLAY PRODS	328X-3299
83 - STEEL	331X-332X,332X,3391,3399
90 - NONIRN WR DRNG&INSUL	3357
92 - METAL CANS	3411
97 - METAL STAMPINGS	3461
98 - CUTLRY, HAND TOOLS	342X
99 - MSC FBRCTD WIRE PRDS	3481
103 - FARM MACHINERY	3522
104 - CNST,MNNG&OIL FLDMAC	3531-3533
105 - FTRLS HNDLING MACHNRY	3534-3537
123 - HOUSEHOLD APPLIANCES	363X
124 - ELEC LTGNG&WIRNG EQP	3641-3644
125 - RADIO & TV RECEIVING	3651

ALMON CODE-NAME	SIC CODES	
127 - COMMUNICATION EQUIP	366X	
128 - ELECTRONIC CMPONENTS	367X	
129 - BATTERIES	3691-3692	
132 - TRK,BUS,&TRLR BODYS	3713-3715	
133 - MTR VEHICLES & PARTS	3711-3712,3714,3717	
134 - AIRCRAFT	3721	
137 - SHP,BOT BLDG EQP&RPR	373X	
139 - TRNSP EQP/CYCLS&PRTS	374X	
140 - TRAILER COACHES	375X-3799	
144 - MDCL & SURGCL INSTRS	384X	
145 - PHOTO EQUIPMENT	3861	
147 - JEWELRY & SILVERWARE	3910,3961	
148 - TOYS,SPTNG GD&MUSICL	393X-394X	
149 - OFFICE SUPPLIES	395X	
150 - MISC MANUF,NEC	3962-3964	
163 - WHOLESALE TRADE	399X	
164 - RETAIL TRADE	52XX-59XX,7390	
170 - PERSNL & RPR SRVCS	72XX,76XX (except 7694,7699 p)	
172 - ADVERTISING	731X	
175 - MEDICAL SERVICES	80X,7220	
182 - BUSINESS TRAVEL		
201 - RSDNTL,FRM,MSC HSNG		1521*
202 - AD&ALTR,MSC-N-BD CST	p 15XX,16XX,17XX	1522*
203 - COMERCIAL CONSTR		1523*
204 - PUBLIC UTILITY CONST		1524*
205 - INSTNL,OFC BLDG CNST		1525*
206 - INDSTRL CONSTRUCTION		1526*
900 - MOTHER EARTH	0001	

NOTE: Construction groups were redrawn in both Almon and SIC Codes.

TABLE 93

SIC PRODUCT CODE DICTIONARY
(NOTE: BLANKS IN CODE NUMBER ARE ZEROS.)

CODE - NAME

10 12 - NUTS IN SHELLS
10 15 - OTHER SEEDS
11201 - RAW COTTON
11211 - COTTONSEED
11300 - MISC GRAIN
11301 - CORN SILAGE
11311 - BARLEY
11321 - CORN
11331 - OATS
11341 - ROUGH RICE
11351 - RYE
11361 - SORGHUM
11362 - SORGHUM FORAGE
11363 - SORGHUM SILAGE
11371 - WHEAT
11381 - SOYBEANS
11391 - HAY
11392 - ALFALFA
11393 - TIMOTHY
11394 - BEANS DRY
11399 - MXD PLTRY,GRAIN (F)
11410 - UNSTEM LEAF TOBACCO
11911 - FLAXSEED
11921 - PEANUTS
11923 - SHELLED PEANUTS
11951 - IRISH POTATOES
11971 - SUGARBEETS
11981 - SUGAR CANE
11991 - POTATOES
11992 - SWEET POTATOES
12211 - FRESH APPLES
12212 - PRUNES
12213 - CRANBERRIES
12214 - GRAPEFRUIT
12215 - LEMONS
12216 - LIMES
12217 - CANTALOPE
12218 - HONEYDEW MELON
12221 - FRESH APRICOTS
12231 - FRESH ORANGES
12241 - FRESH GRAPES
12251 - PLUMS
12261 - FRESH PEACHES
12271 - FRESH PEARS
12273 - FRESH PINEAPPLES
12281 - FRESH STRAWBERRIES
12283 - COCOA BEANS
12285 - GREEN COFFEE

```
CODE  - NAME

12290 - FRESH FRUIT
12291 - OTHER FRESH FRUIT
12301 - FRESH FRUITS
12311 - FRESH PEAS
12321 - FRESH BEANS
12322 - LIMABEANS
12323 - SNAP BEANS
12331 - FRESH CORN
12341 - FRESH TOMATOES
12351 - CUCUMBERS
12380 - LETTUCE
12381 - ONIONS
12382 - GREEN PEPPERS
12383 - SPINACH
12384 - WATERMELON
12391 - OTHER FRESH VEGET.
12392 - ASPARAGUS
12393 - BEETS
12394 - BROCCOLI
12395 - BRUSSEL SPROUTS
12396 - CABBAGE
12397 - CARROTS
12398 - CAULIFLOWER
12399 - CELERY
13  1 - MEAT + LIVESTOCK
13 11 - YOUNG CHICKENS
13 21 - HENS
13205 -   WHOLE     MILK
13291 - DAIRY CATTLE
13431 - TURKEYS
13435 - OTHER POULTRY
13451 - SHELL EGGS
13513 - CATTLE
13523 - CALVES
13633 - HOGS
13943 - SHEEP + LAMBS
14410 - TOBACCO
81111 - STUMPAGE CUT
81121 - HARDWOODS TIMBER
81122 - SOFTWOODS TIMBER
91211 - FINFISH,ROUND
91212 - COD
91213 - FLOUNDER
91214 - HADDOCK
91215 - HERRING
91216 - MACKEREL
91217 - MENHADEN
91218 - SALMON
91219 - SARDINES
91220 - TUNA
91221 - WHITING
91311 - SHELLFISH
```

```
CODE   - NAME

91312 - CLAMS
91313 - CRABS
91314 - OYSTERS
91315 - SHRIMP
201   0 -    MEAT      (F)
201   1 - MEAT PRODUCTS
201101 - SAUSAGE+CANN. MEATS
201102 - OTR MEAT MATERIALS
201104 - TALLOW
201111 - FRESH + FROZEN BEEF
201121 - FRESH + FROZEN VEAL
201131 - FRESH + FROZEN LAMB
201141 - PORK
201151 - LARD
201161 - PROCESSED PORK
201191 - HIDES,SKINS,PELTS
201391 - ANIMAL CASINGS
201501 - DRESSED POULTRY
202311 - DRIED MILK
203   0 -  FRUIT &   VEG (F)
203411 - DRIED FRUITS
203413 - DRIED BEANS
204   1 - GRAIN MILL PRODUCTS
204110 -   FLOUR       (F)
204115 - SEMOLINA
204123 -   WHEAT     GERM
204133 -   HOMINY     FEED
204135 -    CORN      MEAL
204200 - COM MIXED GRAIN
204210 -   GRAIN    FEED (F)
204220 -   GRAIN    FEED (F)
204554 - PREPARED FLOUR MIX
204609 - STARCH
205   0 -  PASTRIES    (F)
205   1 - BAKERY PRODUCTS
206   1 - SUGAR
206 11 -   SUGAR       (F)
206101 - RAW CANE SUGAR
207163 - NUT MEATS
207168 -  FROSTING    (F)
207211 - CHOCOLATE COATINGS
209   6 -   FATS &   OILS F/R
209131 - COTTON LINTERS
209140 -    MEAL       (F)
209141 - COTTONSEED CAKE+MEL
209221 - SOYBEAN CAKE + MEAL
209311 -   LINSEED  OIL F/R
209331 - OTHER OILSEED CAKE
209411 -  INEDIBLE TALLOW/FR
209421 - MEAT MEAL + TANKAGE
209436 - FR MEAL + SOLUBLES
209611 - SHORTENING   F/R
```

```
CØDE   - NAME

214111 - UNSTMD LTØBACC R+PD
214123 - STEMMED LEAF TØBACC
214124 - PRØC SHEET TØBACCØ
214129 - ØTHER TØBACCØ MATER
220  1 - FABRIC PCWØRK, NEC
220 15 -       ØTHER BACKING
220 23 -   SECØNDARY BACKING
220103 -              CØTTØN
220119 - BRØADWØVEN FABRICS
220123 -  BRØADWØVEN FABRICS
220124 -  SUITING+CØATING PG
220125 - ØTHER PIECE GØØDS
220126 - BRØADWØVEN GØØDS
220127 -    ØTHER BRØADWØVEN
220129 - BRØADWØVEN FABRICS
220211 - BRØADWØVEN FABRICS
220234 - CØTTØN FABRICS
220241 - MANMADE FIBRE FABRC
220311 - CØTTØN FABRIC
220313 - NYLØN FABRIC
220903 -         ØTHER YARNS
221101 - BRØADWØVEN CØTTØN
221141 - MATRESS TICKING
221161 - CØTTØN FABRIC
222101 - RAYØN
222103 - ØTHER FABRICS
222105 - NYLØN
225601 - KNIT GØØDS
228 13 - ALL ØTHER YARNS
228 15 - ALL FIBRES
228101 - SPUN YARN
228102 -   CØTTØN FACE YARNS
228110 - CARDED CØTTØN YARNS
228120 - CØMBED CØTTØN YARNS
228130 - RAY +/ØR ACETATE YN
228140 -          SPUN NYLØN
228141 -    NYLØN SPUN YARNS
228145 - ACR + MØDACRYL YNS
228301 - WØØL YARNS
228321 - WØØL + CHIEFLY WØØL
229  1 - MISC. TEXTILES
229 50 -    TEXT      (F)
229 52 -    TEXT      (F)
229 53 -    TEXT      (F)
229 54 -    TEXT      (F)
229 55 -    TEXT      (F)
229308 - PADDINGS
229313 - AUTØ PADS FR CØTTØN
229315 - AUTØ PADS FR ØTHER
229331 - FELTS FRØM CØTTØN
229335 - FELTS FRØM MANMADE
229339 - FELTS FRØM  ØTHER
```

```
 CODE   - NAME

229501 - COATED FABRICS
229503 - PLASTIC FABRICS
229508 - COATED FABRICS
229551 -   PLASTIC LAMIN (F)
229610 - COTTON TIRE CORD &F
229630 - MANMADE    TIRE C&F
229701 - RWL,MHR,AN FBR(SCRD
229704 -           WOOL TOPS
229903 - PAPER
229921 - BURLAP BAGS
229922 -   TEXTILE  BAGS (F)
229923 - JUTE
229999 - FISH NETS    (F)
239  0 - TEXT PRD
239  1 - AUTO UPHLST MAT (F)
239 56 -    TEXT    PRD (F)
239 57 -    TEXT    PRD (F)
239 58 -    TEXT    PRD (F)
239 59 -    TEXT    PRD (F)
239 60 -    TEXT    PRD (F)
239301 - COTTON BAGS
239611 - MENS APPAREL FINDNG
239613 -    HAT    MATERIALS
239615 -  HATTERS     FUR
239626 -    AUTO   TRIMMINGS
239627 -    FURN   TRIMMINGS
239910 - AUTO SEAT CVRS NSK
239912 - FIBER AUTO SEAT CVR
239914 - WOVEN AUTO SEAT CVR
239916 - CL PLAST AUTO STCVR
239919 - OTHER AUTO SEAT CVR
239921 - AUTO/AIR  SEATBELTS
240 11 - PLYWOOD + OTHER WD
241100 - CONST MAT.   (F)
241101 - SPRUCE + TRUE FIR
241102 - HEMLOCK
241103 - JACK PINE
241104 - SOUTHERN PINE
241105 - OTHER SOFTWOODS
241106 - NO MIXED HARDWOODS
241107 - POPLAR
241108 - SO MIXED HARDWOODS
241109 - POLES/PILING ETC
241111 - HARDWOOD
241112 - LOGS BOLTS FLITCHES
241119 - OTHER HARDWOODS
242 11 - WOOD WASTES
242 13 - SLB,CHP,CR+OTRMLWST
242 15 - SLB,CHP,CR+OTRMLWST
242101 - RGH + DR HARDWOOD
242103 - RGH + DR SOFTWOOD
242110 - ROUGH HARDWOOD
```

```
 CODE  - NAME

242111 - ROUGH LUMBER
242118 - ROUGH SOFTWOOD
242120 - DRESSED LUMBER
242121 - DRESSED HARDWOOD
242128 - DRESSED SOFTWOOD
242157 - CHIPS
242622 - RGH HARDWD FURN STK
243100 - CONST MAT.   (F)
243199 -   WD PRD     (F)
243203 - SOFTWOOD PLYWOOD
243210 - HARDWOOD PLYWOOD
243211 - VENEER CORE
243213 - BOARD CORE
243215 - HRD PLWD,CNTANR TYP
243250 - HARDWOOD VENEER
243260 - SOFTWOOD VENEER
243268 -  PLYWOOD     (F)
249930 - PARTICLEBOARD
249960 - HDPRESSED FIBERBORD
249961 -   WD PRD     (F)
249962 -   WD PRD     (F)
249963 -   WD PRD     (F)
249964 -   WD PRD     (F)
249965 -   WD PRD     (F)
249966 -   WD PRD     (F)
249967 -   WD PRD     (F)
249968 -   WD PRD     (F)
249969 -   WD PRD     (F)
249970 -   WD PRD     (F)
249971 -   WD PRD     (F)
249972 -   WD PRD     (F)
249973 -   WD PRD     (F)
249974 -   WD PRD     (F)
251  0 -  HSE FURN    (F)
251111 - WOOD SEWMACH CABINT
251113 - WOOD RADIO/HIFI CAB
251115 - WOOD TV   CABINETS
251911 - PLAS SOUND CABINETS
260 12 - PAPER + PAPERBD PRD
260 91 - PAPER BOXES + SACKS
261101 - WOODPULP
261102 - WPULP PURCH FR MILL
261104 - MKT PURCH WOODPULP
261122 -   LINTER     PULP
262100 - PAPER
262101 - ALL OTHER PAPER
262102 - UNCOATED PAPER
262105 - PAPER
262106 - PURCHASED PAPER
262111 - NEWSPRINT
262112 - NEWSPRINT
262131 - COATED PAPER
```

CODE - NAME

262150 - SPECIALTY PAPERS
262163 - CARBONLESS PAPER
262164 - CARBONIZING TISSUE
263102 - PAPERBOARD
263103 - PAPERBOARD
263105 - PAPERBOARD
263106 - PHOTO PAPER (F)
263107 - PAPER (F)
263112 - PAPERBOARD LINERS
264 1 - PAPER PRODUCTS NEC
264101 - WAX COATEDPAPER (F)
264102 - WAX COATEDPAPER (F)
264103 - WAX COATEDPAPER (F)
264104 - WAX COATEDPAPER (F)
264302 - BAGS,EXCEPT TEXTILE
264338 - PAPER SHIPPING SACK
265 1 - SPCL PAPR PRODS (F)
265 11 - PAPERBOARD CONTAINR
265 13 - PAPERBOARD CONT.
265 15 - BOXES + FLEX. PKG.
265301 - CORRUGATED CONTAIN.
266100 - BLDG PAPER (F)
266101 - ROOFING FELTS
271199 - ADVERTISE SPACE
272199 - ADVERTISE SPACE
275199 - PRINT LABOR
281600 - INORGANIC PIGMENTS
281833 - RUBBER PROC CHEMICA
281835 - PLASTICIZERS
282 11 - MAN MADE FIBER YARN
282 14 - MNMD FBR,STAPLE+TOW
282100 - PLAS MAT. (F)
282101 - PLASTIC MAT + RESIN
282103 - CELLULOSIC PLASTICS
282105 - RAY + ACET STAPLE
282121 - CELLOPHANE
282130 - THERMOPLASTIC RESIN
282137 - VINYL + VCOPOLY RES
282140 - THERMOSETTING RESIN
282202 - SYNTHETIC RUBBER
282203 - SYNTHETIC RUBBER/FR
282204 - BUTYL SYN RUBBER
282205 - NEOPRENE SYN RUBBER
282206 - N-TYPE SYN RUBBER
282208 - POLYURETHANE
282209 - OTHER ELASTOMERS
282210 - STEREO ELASTOMERS
282301 - RAY ACETATE YARN
282305 - RAYON AND ACETATE
282402 - OTH MANMD FILAM YN
282411 - FILAMENT NYLON YARN
282421 - MANMADE FIBER

CODE	NAME
282422	POLYPROPYLENE
282423	BARE SPANDEX THREAD
282428	POLYESTER
285101	PAINTS/VARNISHES ET
285110	PNT,VAR,LAC,JAP,ENM
289111	GLUE ADHESIVE
289501	CARBON BLACK
291106	PETROLEUM WAX
291191	ASPHALT
301100	TIRES + INNER TUBES
301131	TIRES
301141	INNER TUBES
301142	INNER TUBES
301145	INNER TUBES
301146	INNER TUBES
301147	BICYCLE INNER TUBES
306900	RUBBER HEELS & SOLE
306912	AUTONOFLAT BELTS
306914	AGRIC NOFLAT BELTS
306915	NOFLAT V BELTS
306931	RUBBER SLABS
306932	FOAM UPHOLS CUSHION
306933	FOAM RUBBER MAT COR
306937	AUTO CHEMSPG
306942	AUTO MATS RUBBER
306951	HD RUBBER MECH PART
306952	AUTO MOLD RUB MECH
306953	AUTO RUBBR EXTRUSN
306965	RUBBER/ELAST RESINS
306984	RUB.CTD GARM FABRIC
306986	RUB.CTD SHOE FABRIC
307900	PLAS PROD (F)
307901	MISC PLASTIC PROD.
307911	PLASTIC FILM
307913	UNBACK PLASTIC FILM
307914	SYNTHETIC CASINGS
307916	UNSUPPORTED PLASTIC
307921	FOAMPLAS MATTR COR
307922	FOAMPLAS PILLSTOCK
307931	PLASTIC LAM SHEETS
307940	PLASTIC CONTAINERS
307951	AUTO PLASTIC PARTS
307953	AIRCR PLASTIC PARTS
307955	MISSILE PLAST PARTS
307984	COMP + NUCLEAR
311100	FINISHED LEATHER
311102	UPPER LEATHER
311103	LINING LEATHER
311105	INNERSOLE LEATHER
311106	SOLING LEATHER
311107	OTHER FIN LEATHER
311108	FINISHED LEATHER

C0DE - NAME

331 12 - SHEET AND STRIP
331210 - C0KE
386101 - LIGHT SEN. PAPERS
395500 - 0NETIME CARB0N PAPR
941111 - MIXED WASTEPAPER
941112 - WASTE PAPR,NEWSPRNT
941113 - C0RRUG. WASTEPAPER
941114 - PULP SUBSTITUTES
941115 - WST PPR,HI-GD DEINK
941259 - 0T FB IN:RG,STW,BGS
999 0 - ACCUMULATED MISC
999807 - 0THER FIBERS
999823 - W00L N0ILS AND WAST
013200 - DAIRYCOW MANURE (F)
013400 - BROILER CHICKEN MANURE (F)
013401 - TURKEY AND LAYER CHICKEN MANURE (F)
013500 - BEEF CATTLE MANURE (F)
013600 - HOG MANURE (F)
242125 - CONSTRUCTION LUMBER (F)
249975 - WD. PROD. (F)

TABLE 94

DICTIONARY OF MEASURES AND COEFFICIENTS

Coefficient (applies to Table 91 only)

L	Million (=10^6)
K	ten thousand (=10^4)
M	thousand (=10^3)

MEASURE	NAME	WEIGHT
TON, STN	Short ton	2000 lbs
CASE	case	depends on product
CWT	hundred weight	100 lbs.
LTN	long ton	2240 lbs.
LYD	linear yard	depends on product
SYD	square yard	" " "
SF	square feet	" " "
CF	cubic feet	" " "
CORD	Cord (=128 cubic feet)	" " "
BAG	bag	" " "
BALE	bales of cotton	482 lbs./bale
BDF	board feet	depends on product
SF 3/4	square feet, 3/4" thick	" " "
SF 1/8	" " 1/8" "	" " "
SF 3/8	" " 3/8" "	" " "
FLS	feet logscale	
GAL gallons	gallons	" " "
TIRES	tires	" " "
TUBES	tubes	" " "
U	Units	" " "

needed a conversion factor are listed, but not those whose original units were already listed in pounds (LB) or million pounds (LLB).

Field:	Cols	
	1-6	Product code
	7-12 13	Floating point coefficient by which AMT is to be multiplied by to get weight in ounces ("1" in col. 13) or pounds # ("2" in col. 13)
	14-20	dollars/unit given in cols. 21- used in cases where conversion directly from dollars to weight was necessary. Also where the information concerning a given product at a given buyer was used to compute the weight of the same product at another buyer. i.e. dollars to square yards; square yards to pounds.

HEAT CONTENT

Table 96 is the assignment of heat contents for products produced in each SIC four-digit code sector. Because of uncertainties introduced in waste coefficients, and precise material composition, any further delineation of heat content was not warranted. Each category of heat generally covers the following range of individual material heat contents.

Within the range: 5000 - 8500 BTU/LB was given 7500 BTU/LB
Within the range: 8500 -11500 BTU/LB was given 10000 BTU/LB
Within the range: 11500 -15000 BTU/LB was given 12400 BTU/LB

The lowest category is composed of food wastes, natural fibers, paper, and pulp wastes, and agricultural residues. The 10,000 BTU/LB category contains forest, sawmill and lumber products, mixed fibers textile, apparel and rubber products. Synthetic fibers, plastics, animal and vegetable fats and oils, chemicals and petroleum wastes are given 12,500 BTU/LB.

PROJECTIONS

The movement of combustible materials through the economy, and the CSW generated by modification of these materials at points of manufacture, were determined for 1967. The purpose of the model is to determine the expected combustible materials flows and CSW generation for both 1980 and 1990. To do this, the growth of each economic sector was projected by using projected final demand levels for 1980 and 1990 to drive an economic model. When related to base year values for materials purchased and waste generated, CSW loads for those years were predicted.

TABLE 95

CONVERSION FACTORS FOR MATERIALS TRANSACTIONS

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***  SRTCNV  ***    01/09/72    PAGE -   1-

011201   482.2
011301    56.2
011311    48.2
011321    56.2
011331    28.2
011351   55.92
011361    56.2
011371    60.2
011381   59.92
012211   45.02
012261   50.02
012271   53.32
012283   100.2
012285   100.2
012291    55.2     3.9BU
012391     1.2    .055LB
013322    56.2
013451    43.2
081111    1.02    0.05LB
081121   54.02
081122   45.62
201191     1.2     .42LB
201391     1.2     .21LB
206011   100.2
206011   100.2
220001    10.1

220015    1.72    0.71SQYD
220023    1.72

220103    10.1    0.71SQYD
220119    10.1
220123    10.1
220124     1.2
220125    12.1
220126    10.1
220127    10.1
220129    11.1
220211    10.1
220234    10.1
220241    10.1
220311    10.1
220313    10.1
220903    1.02    1.31LB
221101    10.1
221141    10.1
221161    10.1
222101   0.752
222103    10.1
222105   0.752
225601    13.1
228102    1.02   0.682LB
228130    1.02   0.626LB
228140    1.02    1.96LB
228145    1.02    1.31LB
228321    1.02   1.723LB

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229001    10.1
229501    12.1
229503    12.01   1.083LYD
229503    12.1
229508    12.1
229903             0.88SQYD
229903     2.32
229921    13.71
229923             0.13SQYD
239001     .462
239301     .462
240011     4.52
241101  4600.2
241102  4864.2
241103  4600.2
241104  4644.2
241105  4644.2
241106  4864.2
241107  4800.2
241108  4700.2
241109     4.82     .069BDF
241111     5.22
241112     4.32
241119  4700.2
242011  1500.2     12.C0RD
242013  2000.2
242015  1500.2
242101     4.52
242103     3.82
242110     5.22
242111     4.52
242118     4.32
242120     3.32
242121     3.72
242128     3.22
242157  2048.2
242622     5.22
243203    1.022
243210    1.402
243211      .42
243213      .42

243215     1.42    .174SF
243250      .52
243260    1.022
249930     2.22
249960      .72
251111    35.02
251113    35.02
251115    35.02
251911    35.02
260012     1.02   0.20LB
260091   2000.2  400. STN
262100      1.2    .17LB
262101   2000.2   141.STN
262131      1.2    .17LB
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263105    2.51   .145SF

264302    .122  .0043BAG
264338    .242
265001   2000.2
265011  2000.2  400.STN
265013  2000.2  400.STN
265015  2000.2  400.STN
265301  2000.2  400.STN
281833
282121    1.02  0.222LB
282411    1.02    1.96LB
282422    1.02    1.31LB
282428    1.02    1.31LB
285101     8.2
285110    1.02    0.50LB
301100    27.2
301131    27.2
301141   31.52
301142   31.52
301145   31.52
301146   31.52
301147   31.52
306900    1.02      1.0LB
306933    45.2
306941    1.02      1.0LB
306942    1.02      1.0LB
306951    1.02      1.0LB
306952    1.02      1.0LB
306965    1.02      1.0LB
306984    1.02      1.0LB
306986    1.02      1.0LB
307911   0.362 0.1723SQYD
307911    .362
307913   0.142 0.1250SQYD
307913    .362
307914   0.0520.09091SQYD
307914    .362
307922    20.2
307931     6.1     .44SF
307940    1.02    0.37LB
307951    1.02    0.37LB
307953    1.02    0.37LB
307955    1.02    0.37LB
311100     2.1
311102     4.1
311103     3.1
311107     1.2     .57LB
311108     1.2
386101    1.02    0.37LB
970011    1.02    0.37LB
```

TABLE 96

BTU CONTENT CATEGORIES
(products from listed SIC seller codes rated at...)

	7500 BTU/LB	10,000 BTU/LB	12,500 BTU/LB
SIC#	0001	013X	2090-2096
	010X	08XX	2221
	011X	09XX	2262
	012X	201X	2282
	2020-2089	220X	2290
	2098-2099	2241	28XX
	21XX	225X	29XX
	221X	2269	3079
	2231	2280-2281	
	2261	2284	
	227X	23XX	
	2283	24XX	
	2291-2295	25XX	
	2297-2299	3011-3069	
	26XX		
	27XX		
	31XX		
	3955		
	5059		
	5093		

This process consists of two parts:

1. Base year (1967) combustible waste generation data, which is an aggregate summary of the raw data contained in Table 91 displayed in the form of combustible material transactions between Almon-defined sectors.

   At this level of detail, specific materials (i.e. products) and their waste generating and heat characteristics have been combined, and the material flow between two Almon sectors is viewed as an homogeneous material which has the following properties:

   DOLLARS = the sum of the dollar values of those same combustible material transactions, above.

   WEIGHT = the sum of the product material weights bought by SIC sectors within the Almon buying sector, and sold by SIC sectors within the Almon selling sector.

   WASTE = the sum of the wastes generated by the constituent products making up the above flow.

   W/C = WASTE/WEIGHT = weighted mean waste coefficient of materials purchased.

   HEAT = the sum of the heat contents of the constituent products making up the flow.

   H/C = weighted mean heat coefficient of materials, = HEAT/WEIGHT.

2. Projected transaction levels between Almon sectors, for each of two sets of assumptions concerning population growth and economic activity (called B-HI and E-LO) for each of two years, 1980 and 1990. The projected transaction levels are also characterized by DOLLARS, WEIGHT, WASTE, W/C, HEAT, H/C quantities which make it possible to estimate CSW for those two years.

The aggregated base year data and projections are summarized in Table 99 at the end of this appendix.

In Table 91, classification of combustible materials into SIC (and Clopper Almon - CA) economic sectors was primarily a means of achieving an ordered display of detailed materials transfer and waste-generation data. In Table 99, explicit use is made of materials flows through a sequence of economic sectors in order to (1) determine quantitative sector growth interrelationships among buyer and seller sectors and (2) use these interrelationships, with projected demand for goods and services in 1980 and 1990, to predict the activity level (and waste generation level) of each sector for those years.

AGGREGATED BASE YEAR INFORMATION: ALMON SECTOR INTERRELATIONS

The aggregated base year information can be displayed as a square matrix (with some rows = 0 where combustible materials flows were truncated): a "dollar value matrix," with each Almon sector purchasing combustible materials listed horizontally along the top and each sector selling combustible material along the side. The dollar amount of intersector sales/purchases would be given at the intersection of the buyer's column and the seller's row.

The dollar transactions, because they were derived basically from the *Census of Manufactures*, are only intermediate transactions, i.e., the material transacted undergoes re-manufacture before sales to final consumer. In addition to demand generated by sales to intermediate consumers, the growth of any sector will be dependent on sales directly to the final consumer. Therefore, another buying sector was added, Final Demand = FD, and the dollar entries for that column were obtained directly from predicted sales from each Almon sector to final demand.

Entries in the "dollar matrix" are referred to as D_{ij}, equal to the dollar level of transactions from seller "i" to buyer "j".

The weight of combustible materials transferred from sector "i" to sector "j" can be displayed in an equivalent fashion. Similarly, the waste generated at buyer "j" from materials purchased from seller "i" and the heat content of that waste can be displayed.

The "dollar value" array defines the inter-dependence of economic sectors in this model. The entries in the other arrays are tied directly to the level of dollar transactions among sectors. Therefore, the growth 1967-1980 or 1967-1990 of the materials flow between two sectors is assumed to be the same as the growth of the dollar level of transactions, and the growth of CSW generated at the buyer as a consequence of his purchases from that seller.

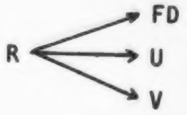
PROJECTION METHODOLOGY

The method for projecting future dollar output level is based on a simple algorithm: the growth of any economic sector, S, is dependent on the growth of those sectors which generate the demand for S's products (e.g., the output level of SIC sector 2421, Sawmills, depends on the behavior of those sectors buying materials from 2421. Their purchases from 2421 create a demand which is reflected back in the growth of 2421.) The influence of each demand on the growth of S is weighted in proportion to the fraction of S's output which goes to that specific sector. This demand could be an intermediate demand (another industrial sector which remanufactures the material before ultimate consumption) or directly to final demand.

Conversely, the growth of any sector, B, will be reflected in the growth of each of those sectors which supply B with materials it needs to produce its products. The aggregation of the raw data (Table 91 is raw data; the aggregation is Table 99, 1967) into Almon-defined industrial groups now shows to what extent all Almon sectors are related to one another, by virtue of material (and dollar) flows among themselves.

Example: Industries in economic sector R make nylon sheets. Half of the dollar value of their product they sell directly to Final Demand. The other half goes to Intermediate Demand; Sector U, which manufactures car seat covers, buys 30% and Sector V, which makes swimsuits, 20%. Sales from R are in the following proportion:

R to FD = 0.50
R to U = 0.30
R to V = 0.20



By 1980, if final demand is projected to be twice its 1967 level (direct consumption will demand twice the amount of nylon sheets), the dollar output levels of sectors U and V are expected to be four and fives times their 1967 value, then the projected dollar output level of sector R in 1980 compared to 1967 is, according to the algorithum used here, is equal to

$$\sum_{\text{All Buyers}} (\text{fraction of seller's output to each buyer}) \times (\text{buyer's growth})$$

or, in this case

$$(0.5)\ (2.0) + (0.3)\ (4.0) + (0.2)\ (5.0) = 3.2$$

The dollar output level (given as a ratio to 1967) of any sector can be determined by knowing:

(1) The fraction of its combustible output going to each demand (intermediate sector or final demand).

(2) The behavior, in time, of those sectors.

The calculationneedn't be done in terms of absolute quantities for either sector output level, or sales to and purchases from other sectors. Sales are dealt with as a fraction of total sales from that sector, in relation to output level in 1967 = base year.

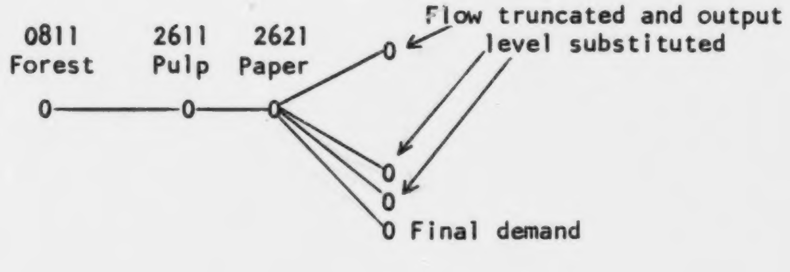
The assumption was made that physical quantity of materials purchased by sector R (in order to make nylon sheets to meet the growing demand) will grow in direct proportion to the output level of sector R. In this case, in 1980 Sector R would be expected to use 3.2 times as much inputs to produce their products, and therefore, further assuming that the process waste coefficient remains constant, will generate 3.2 times as much waste in 1980 as it did in 1967. The validity of these assumptions depend on the sector involved -- some waste coefficients are seen to be chaning quite a lot, some are rather constant.

(1) Before the aggregated raw data (called now Almon: Base Year Data) could be used for this type of projective analysis, the "dollar value" matrix developed previously had to be normalized so that seller's sold fractions of their output (adding to 1.00) to each of their buyers; rather than dollars worth. (An auxiliary array was generated, wherein each element in the "dollar value" array was replaced by an output coefficient

$$T_{ij} = \frac{D_{ij}}{(\Sigma D_{ij} + D_{ij}\text{Final Demand})}$$

(2) In addition, projected growth in buyer-generated demands are needed. All economic activity is ultimately dependent on final consumer demands. The projected levels of consumer demand used to project future waste loads were developed externally by Resources for the Future (RFF). In places where combustible process wastes were no longer generated, some materials flows were terminated and the effect of the final demands were simulated by substituting Almon-model-generated output levels for these flow endpoints. (Since projections are related to base year data, all output levels and final demands were first normalized to base year 1967 data).

Once the output coefficients (T_{ij}) and the future behavior (growth) of buying sectors at the flow endpoints are known, the behavior of combustible waste generating sectors can be determined, by tracing flows backwards from the end (final demand or point of truncation) viz:



The dollar output levels for all sectors at which flows were terminated were given as inputs to the computer, and the program traced back through the materials flows, calculating projected output levels for combustible waste generating sectors enroute, and increasing materials flows, waste and heat generating flows proportionately.

RATIOS OF FINAL DEMAND (RFD)

It was established above that the present and future activity level of each economic sector is dependent on demand for its product, as an Intermediate Demand (ID) or as Final Demand (FD), or both. The quantitative nature of these dependencies is given by the "economic model".

It was further established that, for purposes of prediction, using the model developed for this study, the relevant demand parameter was the ratio of the predicted future demand to the known base year (1967) demand, (RFD = Ratio Final Demand). These ratios are the contents of Table 97 . The first column gives the line number, the second the Almon sector number, and the remaining four give the ratios of final demand for both the Population Level B, high economic activity (B-HI), and Population Level E, low economic activity, defined below. For example, line 18 shows that the Final Demand for Almon Sector 41 (Sawmills) in 1980 will be 1.774 times its 1967 level, according to the B-HI projections, but only 1.605 times as high according to the E-LO projections. Notice that Almon sectors 4,5,47,11, and 12 are all zeros. This has removed final demand as an influence to the growth rate of those sectors, and the projected output level has therefore dependent solely on intermediate demands.

RATES OF OUTPUT LEVEL (RØL)

For purposes of calculation, some flows were truncated because combustible wastes were no longer generated (the raw data, however, includes all combustible materials flows). These flows were 'sealed' by the buying sectors output level, whose growth simulated a final demand further down the flow. These output levels were calculated by strict Almon model projected levels, which in turn were driven by the same sets of final demands projections used in our model directly. The format for the RØL table (Table 98) is the same as that for RFD above.

PROJECTION LEVELS

Two projection levels are used. Final demand, the ultimate driver of the economy, depends on many factors, major among them are population, income, level of economic activity. Several projected sets of final demand were generated, incorporating different

TABLE 97

RATIO FINAL DEMAND

	ALMON	B-HI		E-LO	
	NUM	1980/1967	1990/1967	1980/1967	1990/1967
1.	1	0.918	1.917	0.831	1.630
2.	2	1.418	1.725	1.389	1.610
3.	3	1.256	1.514	1.212	1.368
4.	4	0.000	0.000	0.000	0.000
5.	5	0.000	0.000	0.000	0.000
6.	7	1.488	2.110	1.411	1.822
7.	23	1.565	1.912	1.508	1.711
8.	24	1.384	1.973	1.309	1.715
9.	25	1.664	1.819	1.619	1.656
10.	26	1.562	1.539	1.509	1.405
11.	27	1.292	1.950	1.206	1.660
12.	28	1.578	1.905	1.510	1.693
13.	32	1.512	1.604	1.486	1.489
14.	35	1.814	3.935	1.882	3.610
15.	37	1.788	2.745	1.741	2.482
16.	38	2.075	2.435	2.314	2.391
17.	40	1.807	2.674	1.786	2.466
18.	41	1.774	2.424	1.623	2.025
19.	42	1.729	2.380	1.605	2.050
20.	47	0.000	0.000	0.000	0.000
21.	48	1.999	2.954	1.855	2.460
22.	50	1.491	2.112	1.355	1.758
23.	53	1.930	3.028	1.721	2.334
24.	54	1.857	3.032	1.676	2.499
25.	64	0.865	1.058	0.865	1.058
26.	65	0.863	1.052	0.863	1.078
27.	75	1.438	1.875	1.250	1.562
28.	6	2.252	3.372	2.115	2.876
29.	29	1.373	1.500	1.322	1.344
30.	30	1.619	1.840	1.657	1.958
31.	31	1.612	1.809	1.546	1.601
32.	33	1.338	1.553	1.271	1.463
33.	34	1.487	2.026	1.501	1.996
34.	36	2.472	3.259	2.054	2.041
35.	39	1.737	2.512	1.588	2.038
36.	45	2.052	4.057	1.768	3.106
37.	46	1.345	2.071	1.231	1.688
38.	76	1.428	2.760	0.793	1.539
39.	77	1.689	2.467	1.556	2.103
40.	132	1.266	1.823	1.154	1.479
41.	133	1.639	2.349	1.560	2.056
42.	144	2.439	4.522	2.241	3.804
43.	137	1.175	1.643	1.164	1.553
44.	140	1.700	2.522	1.648	2.254
45.	145	1.662	2.323	1.614	2.130
46.	148	1.696	2.811	1.712	2.552
47.	170	1.817	2.000	1.778	1.798
48.	175	2.061	3.285	1.850	2.623
49.	11	0.000	0.000	0.000	0.000
50.	12	0.000	0.000	0.000	0.000

TABLE 98

RATES OF OUTPUT LEVEL

	ALMON NUM	B-HI		E-LO	
		1980/1967	1990/1967	1980/1967	1990/1967
1.	8	1.189	1.721	1.066	1.377
2.	19	1.739	2.568	1.682	2.193
3.	43	1.644	2.336	1.509	1.952
4.	44	1.404	1.878	1.332	1.646
5.	46	1.330	1.993	1.215	1.678
6.	49	1.697	2.418	1.601	2.087
7.	51	1.626	2.287	1.522	1.945
8.	52	1.683	2.519	1.549	2.093
9.	55	1.667	2.338	1.564	2.003
10.	61	1.509	2.032	1.415	1.756
11.	62	2.033	3.520	1.877	2.942
12.	63	1.471	1.996	1.366	1.694
13.	66	1.534	2.649	1.543	2.474
14.	67	1.670	1.982	1.621	1.757
15.	69	1.521	1.886	1.474	1.766
16.	71	1.803	2.500	1.632	2.080
17.	72	1.459	1.848	1.371	1.592
18.	73	1.563	2.438	1.414	2.013
19.	74	2.218	3.508	2.025	2.868
20.	81	1.628	2.200	1.426	1.774
21.	83	1.236	1.530	1.134	1.283
22.	99	1.532	2.131	1.399	1.775
23.	149	1.803	2.739	1.643	2.242
24.	150	1.502	2.167	1.397	1.824
25.	163	1.581	2.183	1.481	1.867
26.	164	1.598	2.196	1.507	1.897
27.	172	1.640	2.276	1.555	1.978
28.	201	2.007	2.879	1.862	2.380
29.	203	1.489	2.169	1.450	2.045
30.	205	2.086	3.061	1.972	2.860
31.	206	1.344	1.897	1.344	1.896
32.	20	1.471	1.987	1.428	1.832
33.	68	1.652	2.396	1.530	2.022
34.	78	1.639	2.718	1.497	2.230
35.	82	1.569	2.165	1.446	1.835
36.	90	1.443	1.960	1.331	1.642
37.	92	1.541	1.838	1.492	1.677
38.	97	1.672	2.507	1.469	1.954
39.	98	1.739	2.743	1.480	2.033
40.	103	1.338	1.759	1.250	1.479
41.	104	1.389	1.799	1.286	1.537
42.	105	1.214	1.675	1.139	1.461
43.	123	2.015	3.759	1.730	2.796
44.	124	1.687	2.459	1.497	1.975
45.	125	1.751	1.500	1.717	1.411
46.	127	1.111	1.485	1.065	1.330
47.	128	1.548	1.947	1.473	1.702
48.	129	1.445	1.803	1.366	1.559
49.	134	1.123	1.563	1.072	1.385
50.	147	1.915	2.818	1.815	2.408
51.	182	1.641	2.363	1.523	1.992
52.	202	1.239	1.683	1.239	1.683

	ALMON	B-HI		E-LO	
	NUM	1980/1967	1990/1967	1980/1967	1990/1967
53.	204	1.207	1.025	0.947	1.006
54.	32	1.512	1.604	1.486	1.489
55.	41	1.774	2.424	1.623	2.025
56.	29	1.373	1.500	1.322	1.344
57.	30	1.619	1.840	1.657	1.958
58.	31	1.612	1.809	1.546	1.601
59.	33	1.338	1.553	1.271	1.463
60.	34	1.487	2.026	1.501	1.996
61.	36	2.472	3.259	2.054	2.041
62.	39	1.737	2.512	1.588	2.038
63.	45	2.052	4.057	1.768	3.106
64.	76	1.428	2.760	0.793	1.539
65.	77	1.689	2.467	1.556	2.103
66.	132	1.266	1.823	1.154	1.479
67.	133	1.639	2.349	1.560	2.056
68.	144	2.439	4.522	2.241	3.804
69.	137	1.175	1.643	1.164	1.553
70.	140	1.700	2.522	1.648	2.254
71.	145	1.662	2.323	1.614	2.130
72.	148	1.696	2.811	1.712	2.552
73.	170	1.817	2.000	1.778	1.798
74.	175	2.061	3.285	1.850	2.623
75.	6	1.258	1.625	1.318	1.733
76.	25	1.664	1.819	1.619	1.656
77.	27	1.293	1.946	1.207	1.659
78.	50	1.678	2.385	1.553	2.047
79.	53	1.819	2.739	1.657	2.197
80.	75	1.484	2.703	0.950	1.648
81.	23	1.564	1.909	1.508	1.708
82.	24	1.383	1.973	1.309	1.715
83.	42	1.742	2.619	1.592	2.180
84.	54	1.853	3.000	1.674	2.466
85.	1	1.365	1.970	1.290	1.712
86.	2	1.504	1.834	1.459	1.668
87.	3	1.558	1.901	1.502	1.701
88.	38	1.973	2.456	2.096	2.284
89.	48	1.716	2.535	1.591	2.129
90.	26	1.500	1.763	1.443	1.582
91.	5	1.619	1.955	1.563	1.761
92.	28	1.519	1.844	1.456	1.641
93.	7	1.488	1.947	1.424	1.716
94.	40	1.671	2.424	1.613	2.162
95.	37	1.656	2.448	1.541	2.066
96.	35	1.845	2.744	1.715	2.239
97.	4	1.843	2. 741	1.715	2.239
98.	12	1.586	2.344	1.476	1.978
99.	64	1.835	2.632	1.761	2.221
100.	65	1.964	2.779	1.804	2.183
101.	11	1.576	2.329	1.466	1.965
102.	47	1.742	2.577	1.622	2.167

assumptions concerning all the variables on which final demand depends. In order to get an estimate of the sensitivity of combustible waste generation on these variables, two sets of projections were used and developed.

The E-LO projections use the Bureau of the Census E-level population projections and a low-economic activity level, 1.00% reduction per year in hours of work per man. The B-HI projections are based on B-level population projections, and as 0.25% reduction per year in norms of work per man.

FORMAT OF TABLE 99

The format is slightly different than that of Table 91. The sector identification is entirely in Almon numbers. Again, all transactions are sorted by the Almon buyer, whose Almon number and name are listed at the top of the first page. Buyers again are listed in ascending order as are sellers within buyers. Pages are numbered in the upper right hand corner, beginning with each time a new buyer is reached.

Below the Buyer's introduction are the column headings:

DOLLARS	WEIGHT	W/C	WASTE	H/C	HEAT
Millions	Mln.Lbs		Mln. Lbs.		Bln. Btu

Below that is listed the first sequential seller: number and name.

DOLLARS MILLIONS	is the buyer's dollar value (in million dollars) of purchases from that particular seller
WEIGHT MLN LBS	total weight of combustible material transacted (purchased)
W/C	the weighted mean w/c of all specific material flows.
WASTE	W/C WEIGHT
H/C	the weighted mean heat coefficient for the waste
HEAT BLN BTUs	=WASTE x H/C, is the heat content available in the quantity of waste generated in the buyer's sector as a result of the purchase from the seller of that given amount of material.

Below each base year level are listed the model-projected flow levels for 1980 and 1990, B-HI projection and E-LO projections defined above.

TABLE 99

Combustible Material Flows - Almon Sectors (1967;1980, 1990)

listing:

- Almon Economic Sector Seller and Buyer
- Dollar Value of Transaction
- Physical Quantity of Material Transferred
- Mean Waste Coefficient
- Total Waste generated at buyer from materials purchased
- Mean Heat Coefficient
- Heat Content of Dry Wastes
- B-HI and E-L0 Projections for 1980 and 1990

```
BUYER      1 - DAIRY FARM PRØDUCTS
                                                                            PAGE 1
                    DØLLARS         WEIGHT        W/C         WASTE        H/C        HEAT
                    MILLIØNS        MLN LBS                   MLN LBS                 BLN BTUS
SELLER     5 - GRAINS

    1967            1390.00        67100.0       0.000          0.00       0.0         0.00

B-HI
    1980            1897.03        91575.9       0.000          0.00       0.0         0.00
    1990            2738.75       132209.0       0.000          0.00       0.0         0.00
E-LØ
    1980            1792.85        86546.8       0.000          0.00       0.0         0.00
    1990            2379.05       114844.9       0.000          0.00       0.0         0.00

SELLER    26 - GRAIN MILL PRØDUCTS

    1967             504.40        13600.0       0.000          0.00       0.0         0.00

B-HI
    1980             688.39        18560.8       0.000          0.00       0.0         0.00
    1990             993.83        26796.5       0.000          0.00       0.0         0.00
E-LØ
    1980             650.58        17541.5       0.000          0.00       0.0         0.00
    1990             863.30        23277.1       0.000          0.00       0.0         0.00

SELLER    32 - FATS & ØILS

    1967              54.60          893.0       0.000          0.00       0.0         0.00

B-HI
    1980              74.52         1218.7       0.000          0.00       0.0         0.00
    1990             107.58         1759.5       0.000          0.00       0.0         0.00
E-LØ
    1980              70.42         1151.8       0.000          0.00       0.0         0.00
    1990              93.45         1528.4       0.000          0.00       0.0         0.00

SELLER   900 - MØTHER EARTH

    1967               0.00            0.0       0.000      84900.00       7.5    636750.00

B-HI
    1980               0.00            0.0       0.000     115868.77       7.5    869015.75
    1990               0.00            0.0       0.000     167280.78       7.5   1254606.00
E-LØ
    1980               0.00            0.0       0.000     109505.58       7.5    821291.75
    1990               0.00            0.0       0.000     145310.44       7.5   1089828.25

TØTALS

    1967             1949.0        81593.0                   84900.0                636750.0

B-HI
    1980             2659.9       111355.5                  115868.8                869015.8
    1990             3840.2       160764.9                  167280.8               1254606.0
E-LØ
    1980             2513.9       105240.1                  109505.6                821291.7
    1990             3335.8       139650.3                  145310.4               1089828.2
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ANDERSON JACOBSON, INC.

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BUYER      2 - POULTRY & EGGS                                                  PAGE 1

                 DOLLARS      WEIGHT      W/C        WASTE       H/C        HEAT
                MILLIONS     MLN LBS               MLN LBS                BLN BTUS

SELLER     5 - GRAINS

     1967        558.00      33100.0    0.000         0.00       0.0         0.00

B-HI
     1980        839.51      49798.7    0.000         0.00       0.0         0.00
     1990       1023.45      60710.3    0.000         0.00       0.0         0.00
E-L0
     1980        814.37      48307.9    0.000         0.00       0.0         0.00
     1990        930.78      55212.7    0.000         0.00       0.0         0.00

SELLER    26 - GRAIN MILL PRODUCTS

     1967       1513.40      37000.0    0.000         0.00       0.0         0.00

B-HI
     1980       2276.90      55666.2    0.000         0.00       0.0         0.00
     1990       2775.80      67863.5    0.000         0.00       0.0         0.00
E-L0
     1980       2208.73      53999.7    0.000         0.00       0.0         0.00
     1990       2524.44      61718.1    0.000         0.00       0.0         0.00

SELLER    32 - FATS & OILS

     1967        131.70       2170.0    0.000         0.00       0.0         0.00

B-HI
     1980        198.14       3264.7    0.000         0.00       0.0         0.00
     1990        241.56       3980.1    0.000         0.00       0.0         0.00
E-L0
     1980        192.21       3167.0    0.000         0.00       0.0         0.00
     1990        219.68       3619.7    0.000         0.00       0.0         0.00

SELLER   900 - MOTHER EARTH

     1967          0.00          0.0    0.000      15050.0       7.5     112875.0

B-HI
     1980          0.00          0.0    0.000      22650.3       7.5     169877.3
     1990          0.00          0.0    0.000      27601.7       7.5     207012.8
E-L0
     1980          0.00          0.0    0.000      21973.0       7.5     164797.5
     1990          0.00          0.0    0.000      25103.4       7.5     188275.5

TOTALS

     1967        2203.1      72270.0              15050.0                112875.0

B-HI
     1980        3314.5     108729.6              22650.3                169877.3
     1990        4040.8     132553.9              27601.7                207012.8
E-L0
     1980        3215.3     105474.6              21973.0                164797.5
     1990        3674.9     120550.5              25103.4                188275.5
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BUYER      3 - MEAT,MISC LVSTK PRD*                                              PAGE 1

                    DOLLARS       WEIGHT      W/C        WASTE       H/C        HEAT
                   MILLIONS      MLN LBS                MLN LBS                BLN BTUS

SELLER     5 - GRAINS

     1967          4202.40      184850.9    0.000           0.00     0.0         0.00

B-HI
     1980          6546.51      287961.5    0.000           0.00     0.0         0.00
     1990          7988.07      351371.0    0.000           0.00     0.0         0.00
E-LO
     1980          6310.93      277599.0    0.000           0.00     0.0         0.00
     1990          7150.17      314514.5    0.000           0.00     0.0         0.00

SELLER    26 - GRAIN MILL PRODUCTS

     1967          1253.10       39936.0    0.000           0.00     0.0         0.00

B-HI
     1980          1952.08       62212.5    0.000           0.00     0.0         0.00
     1990          2381.94       75911.7    0.000           0.00     0.0         0.00
E-LO
     1980          1881.84       59973.7    0.000           0.00     0.0         0.00
     1990          2132.09       67949.1    0.000           0.00     0.0         0.00

SELLER    32 - FATS & OILS

     1967          2705.00        4460.0    0.000           0.00     0.0         0.00

B-HI
     1980          4213.86        6947.8    0.000           0.00     0.0         0.00
     1990          5141.76        8477.7    0.000           0.00     0.0         0.00
E-LO
     1980          4062.22        6697.8    0.000           0.00     0.0         0.00
     1990          4602.42        7588.5    0.000           0.00     0.0         0.00

SELLER   900 - MOTHER EARTH

     1967             0.00           0.0    0.000      310500.00     7.5 2328750.00

B-HI
     1980             0.00           0.0    0.000      483698.19     7.5 3627736.50
     1990             0.00           0.0    0.000      590209.12     7.5 4426568.00
E-LO
     1980             0.00           0.0    0.000      466291.94     7.5 3497189.50
     1990             0.00           0.0    0.000      528300.12     7.5 3962251.00

TOTALS

     1967           8160.5      229246.9                310500.0                2328750.0

B-HI
     1980          12712.5      357121.7                483698.2                3627736.5
     1990          15511.8      435760.4                590209.1                4426568.0
E-LO
     1980          12255.0      344270.4                466291.9                3497189.5
     1990          13884.7      390052.0                528300.1                3962251.0
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BUYER      4 - COTTON                                                         PAGE 1

                     DOLLARS       WEIGHT       W/C        WASTE        H/C        HEAT
                    MILLIONS      MLN LBS                 MLN LBS                BLN BTUS

SELLER  900 - MOTHER EARTH

     1967             0.00        3740.0       3.2        11950.0       7.5      89625.00

B-HI
     1980             0.00        6892.8       3.2        22023.9       7.5      65179.25
     1990             0.00       10247.6       3.2        32743.0       7.5     245572.50
E-LO
     1980             0.00        6414.1       3.2        20494.3       7.5     153705.00
     1990             0.00        8373.9       3.2        26756.1       7.5     200670.00

TOTALS

     1967              0.0        3740.0                  11950.0                89625.00

B-HI
     1980              0.0        6892.8                  22023.9                65179.25
     1990              0.0       10247.6                  32743.0               245572.50
E-LO
     1980              0.0        6414.1                  20494.3               153705.00
     1990              0.0        8373.9                  26756.1               200670.00
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BUYER      5 - GRAINS                                                    PAGE 1

                  DOLLARS      WEIGHT      W/C        WASTE      H/C       HEAT
                 MILLIONS     MLN LBS               MLN LBS              BLN BTUS

SELLER     5 - GRAINS

      1967        546.50     214600.0    0.000         0.00      0.0        0.00

B-HI
      1980        884.83     347454.8    0.000         0.00      0.0        0.00
      1990       1068.42     419546.4    0.000         0.00      0.0        0.00
E-LO
      1980        854.40     335504.9    0.000         0.00      0.0        0.00
      1990        962.28     377869.4    0.000         0.00      0.0        0.00

SELLER    37 - MISC TEXTILES*

      1967         21.80        130.8    0.000         0.00      0.0        0.00

B-HI
      1980         35.30        211.8    0.000         0.00      0.0        0.00
      1990         42.62        255.7    0.000         0.00      0.0        0.00
E-LO
      1980         34.08        204.5    0.000         0.00      0.0        0.00
      1990         38.39        230.3    0.000         0.00      0.0        0.00

SELLER   900 - MOTHER EARTH

      1967          0.00     508928.3    0.618     314360.0      7.5   2358700.0

B-HI
      1980          0.00     823954.9    0.618     508948.8      7.5   3818735.3
      1990          0.00     994954.8    0.618     614573.8      7.5   4611258.5
E-LO
      1980          0.00     795454.9    0.618     491344.7      7.5   3686648.1
      1990          0.00     896222.7    0.618     553588.0      7.5   4153670.7

TOTALS

      1967         568.3     723656.1              314360.0            2358700.0

B-HI
      1980         920.1    1171621.5              508948.8            3818735.3
      1990        1111.0    1414756.9              614573.8            4611258.5
E-LO
      1980         888.5    1131164.3              491344.7            3686648.1
      1990        1000.7    1274322.4              553588.0            4153670.7
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ANDERSON JACOBSON INC.

BUYER 6 - TOBACCO

	DOLLARS MILLIONS	WEIGHT MLN LBS	W/C	WASTE MLN LBS	H/C	HEAT BLN BTUS
SELLER 900 - MOTHER EARTH						
1967	0.00	1968.0	0.198	390.4	7.5	2925.0
B-HI						
1980	0.00	2475.7	0.198	491.1	7.5	3679.7
1990	0.00	3198.0	0.198	634.4	7.5	4753.1
E-LO						
1980	0.00	2593.8	0.198	514.5	7.5	3855.1
1990	0.00	3410.5	0.198	676.6	7.5	5069.0
TOTALS						
1967	0.0	1968.0		390.4		2925.0
B-HI						
1980	0.0	2475.7		491.1		3679.7
1990	0.0	3198.0		634.4		4753.1
E-LO						
1980	0.0	2593.8		514.5		3855.1
1990	0.0	3410.5		676.6		5069.0

BUYER 7 - FRUIT & VEG

	DOLLARS MILLIONS	WEIGHT MLN LBS	W/C	WASTE MLN LBS	H/C	HEAT BLN BTUS
SELLER 40 - HOUSEHOLD TEXTILES*						
1967	46.20	277.0	0.000	0.00	0.0	0.00
B-HI						
1980	68.74	412.2	0.000	0.00	0.0	0.00
1990	89.94	539.3	0.000	0.00	0.0	0.00
E-LO						
1980	65.80	394.5	0.000	0.00	0.0	0.00
1990	79.29	475.4	0.000	0.00	0.0	0.00
SELLER 900 - MOTHER EARTH						
1967	0.00	204065.0	0.103	21114.0	7.5	158356.0
B-HI						
1980	0.00	303648.7	0.103	31417.6	7.5	235633.7
1990	0.00	397314.6	0.103	41109.0	7.5	308319.1
E-LO						
1980	0.00	290588.6	0.103	30066.3	7.5	225498.9
1990	0.00	350175.5	0.103	36231.6	7.5	271738.9
TOTALS						
1967	46.2	204333.0		21114.0		158356.0
B-HI						
1980	68.7	304060.9		31417.6		235633.7
1990	89.9	397853.9		41109.0		308319.1
E-LO						
1980	65.8	290983.1		30066.3		225498.9
1990	79.3	350650.9		36231.6		271738.9

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BUYER      8 - FRSTRY & FSHRY PRODS                                      PAGE 1

                     DOLLARS        WEIGHT      W/C        WASTE      H/C        HEAT
                    MILLIONS       MLN LBS                MLN LBS              BLN BTUS

SELLER    37 - MISC TEXTILES*

    1967               59.90         360.0    0.000          0.00     0.0          0.00

B-HI
    1980               71.19         427.9    0.000          0.00     0.0          0.00
    1990              103.08         619.5    0.000          0.00     0.0          0.00
E-LO
    1980               63.83         383.6    0.000          0.00     0.0          0.00
    1990               82.51         495.9    0.000          0.00     0.0          0.00

SELLER   900 - MOTHER EARTH

    1967                0.00      460000.0    0.113      52000.00     7.5     390000.00

B-HI
    1980                0.00      546733.8    0.113      61828.00     7.5     463710.00
    1990                0.00      791632.7    0.113      89492.00     7.5     671190.00
E-LO
    1980                0.00      490156.7    0.113      55432.00     7.5     415740.00
    1990                0.00      633617.1    0.113      69524.00     7.5     521430.00

TOTALS

    1967                59.9      460360.0               52000.00             390000.00

B-HI
    1980                71.2      547161.6               61828.00             463710.00
    1990               103.1      792252.2               89492.00             671190.00
E-LO
    1980                63.8      490540.2               55432.00             415740.00
    1990                82.5      634112.9               69524.00             521430.00
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BUYER     12 - WOOL PROCESSORS*                                              PAGE 1

                  DOLLARS      WEIGHT       W/C        WASTE       H/C        HEAT
                 MILLIONS     MLN LBS                 MLN LBS              BLN BTUS

SELLER    11 - WOOL SOURCES*

      1967        155.30        746.3     0.075         55.97      10.0       559.72

B-HI
      1980        246.26       1183.4     0.075         88.75      10.0       887.56
      1990        364.02       1749.3     0.075        131.19      10.0      1311.96
E-LO
      1980        229.17       1101.3     0.075         82.59      10.0       825.96
      1990        307.16       1476.1     0.075        110.70      10.0      1107.04

TOTALS

      1967         155.3        746.3                    56.0                  559.7

B-HI
      1980         246.3       1183.4                    88.8                  887.6
      1990         364.0       1749.3                   131.2                 1312.0
E-LO
      1980         229.2       1101.3                    82.6                  826.0
      1990         307.2       1476.1                   110.7                 1107.0
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ANDERSON JACOBSON, INC.

BUYER 19 - MAINTNC & RPR CONSTR

	DOLLARS MILLIONS	WEIGHT MLN LBS	W/C	WASTE MLN LBS	H/C	HEAT BLN BTUS
SELLER 41 - LMBR & WOOD PRODUCTS						
1967	692.00	1384.0	0.075	103.80	10.0	1038.00
B-HI						
1980	1238.29	2476.6	0.075	185.74	10.0	1857.44
1990	1776.84	3553.7	0.075	266.53	10.0	2665.27
E-LO						
1980	1163.76	2327.5	0.075	174.56	10.0	1745.64
1990	1517.62	3035.2	0.075	227.64	10.0	2276.44
SELLER 42 - VENEER & PLYWOOD						
1967	111.00	313.0	0.100	31.30	10.0	313.00
B-HI						
1980	198.63	560.1	0.100	56.01	10.0	560.09
1990	285.01	803.7	0.100	80.37	10.0	803.69
E-LO						
1980	186.67	526.4	0.100	52.64	10.0	526.38
1990	243.43	686.4	0.100	68.64	10.0	686.44
SELLER 43 - MILLWORK & WOOD PROD						
1967	161.00	322.0	0.075	24.15	10.0	241.50
B-HI						
1980	288.10	576.2	0.075	43.21	10.0	432.15
1990	413.40	826.8	0.075	62.01	10.0	620.10
E-LO						
1980	270.76	541.5	0.075	40.61	10.0	406.14
1990	353.09	706.2	0.075	52.96	10.0	529.63
SELLER 50 - WALL & BLDG PAPER						
1967	63.00	126.0	0.060	7.56	7.5	56.70
B-HI						
1980	112.73	225.5	0.060	13.53	7.5	101.46
1990	161.76	323.5	0.060	19.41	7.5	145.59
E-LO						
1980	105.95	211.9	0.060	12.71	7.5	95.35
1990	138.17	276.3	0.060	16.58	7.5	124.35
SELLER 74 - MISC PLSTC PRODS						
1967	149.00	299.0	0.022	6.58	12.5	82.23
B-HI						
1980	266.63	535.0	0.022	11.77	12.5	147.15
1990	382.59	767.7	0.022	16.90	12.5	211.14
E-LO						
1980	250.58	502.8	0.022	11.07	12.5	138.29
1990	326.77	655.7	0.022	14.43	12.5	180.34

BUYER 19 - MAINTNC & RPR CONSTR

	DOLLARS MILLIONS	WEIGHT MLN LBS	W/C	WASTE MLN LBS	H/C	HEAT BLN BTUS
TOTALS						
1967	1176.0	2444.0		173.4		1731.4
B-HI						
1980	2104.4	4373.4		310.3		3098.3
1990	3019.6	6275.4		445.2		4445.8
E-LO						
1980	1977.7	4110.2		291.6		2911.8
1990	2579.1	5359.9		380.3		3797.2

ANDERSON JACOBSON, INC.

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BUYER    20 - CMPLETE GUIDED MSSLS                                                PAGE 1

                    DOLLARS        WEIGHT       W/C          WASTE        H/C        HEAT
                    MILLIONS       MLN LBS                   MLN LBS                 BLN BTUS

SELLER   74 - MISC PLSTC PRODS

     1967             45.00         121.6     0.022           2.68       12.5        33.45

B-HI
     1980             66.20         178.9     0.022           3.94       12.5        49.21
     1990             89.39         241.6     0.022           5.32       12.5        66.45
E-LO
     1980             64.28         173.7     0.022           3.83       12.5        47.78
     1990             82.45         222.8     0.022           4.91       12.5        61.29

TOTALS

     1967             45.0          121.6                     2.7                    33.4

B-HI
     1980             66.2          178.9                     3.9                    49.2
     1990             89.4          241.6                     5.3                    66.4
E-LO
     1980             64.3          173.7                     3.8                    47.8
     1990             82.4          222.8                     4.9                    61.3
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BUYER 23 - MEAT PRØDUCTS

		DØLLARS MILLIØNS	WEIGHT MLN LBS	W/C	WASTE MLN LBS	H/C	HEAT BLN BTUS
SELLER 2 - PØULTRY & EGGS							
	1967	1960.94	12501.0	0.000	0.00	0.0	0.00
B-HI							
	1980	3066.90	19551.5	0.000	0.00	0.0	0.00
	1990	3743.79	23866.7	0.000	0.00	0.0	0.00
E-LØ							
	1980	2956.72	18849.1	0.000	0.00	0.0	0.00
	1990	3349.81	21355.1	0.000	0.00	0.0	0.00
SELLER 3 - MEAT,MISC LVSTK PRD*							
	1967	11151.37	51439.4	0.005	259.80	10.0	2597.90
B-HI							
	1980	17440.68	80450.9	0.005	406.33	10.0	4063.10
	1990	21289.99	98207.2	0.005	496.01	10.0	4959.86
E-LØ							
	1980	16814.13	77560.8	0.005	391.73	10.0	3917.13
	1990	19049.51	87872.2	0.005	443.81	10.0	4437.90
SELLER 23 - MEAT PRØDUCTS							
	1967	2539.75	6968.0	0.003	19.60	10.0	195.97
B-HI							
	1980	3972.15	10898.0	0.003	30.65	10.0	306.50
	1990	4848.84	13303.3	0.003	37.42	10.0	374.14
E-LØ							
	1980	3829.46	10506.5	0.003	29.55	10.0	295.49
	1990	4338.57	11903.3	0.003	33.48	10.0	334.77
SELLER 38 - KNITTING							
	1967	15.10	49.4	0.040	1.98	10.0	19.76
B-HI							
	1980	23.62	77.3	0.040	3.10	10.0	30.90
	1990	28.83	94.3	0.040	3.78	10.0	37.73
E-LØ							
	1980	22.77	74.5	0.040	2.99	10.0	29.79
	1990	25.79	84.4	0.040	3.38	10.0	33.76
SELLER 49 - PAPER PRØD, NEC							
	1967	87.00	352.0	0.040	14.08	7.5	105.60
B-HI							
	1980	136.07	550.5	0.040	22.02	7.5	165.16
	1990	166.10	672.0	0.040	26.88	7.5	201.61
E-LØ							
	1980	131.18	530.7	0.040	21.23	7.5	159.22
	1990	148.62	601.3	0.040	24.05	7.5	180.39

BUYER 23 - MEAT PRODUCTS

	DOLLARS MILLIONS	WEIGHT MLN LBS	W/C	WASTE MLN LBS	H/C	HEAT BLN BTUS
SELLER 74 - MISC PLSTC PRODS						
1967	227.94	383.2	0.002	0.66	12.6	8.29
B-HI						
1980	356.50	599.3	0.002	1.03	12.6	12.97
1990	435.18	731.5	0.002	1.26	12.6	15.83
E-LO						
1980	343.69	577.7	0.002	1.00	12.6	12.50
1990	389.38	654.6	0.002	1.13	12.6	14.16
TOTALS						
1967	15982.1	71693.0		296.1		2927.5
B-HI						
1980	24995.9	112127.4		463.1		4578.6
1990	30512.7	136875.0		565.3		5589.2
E-LO						
1980	24097.9	108099.3		446.5		4414.1
1990	27301.7	122470.7		505.9		5001.0

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BUYER    24 - DAIRY PRODUCTS
                                                                      PAGE 1
                DOLLARS       WEIGHT      W/C        WASTE      H/C       HEAT
                MILLIONS      MLN LBS                MLN LBS              BLN BTUS
SELLER    1 - DAIRY FARM PRODUCTS

      1967      4679.00      96100.0     0.000        0.00      0.0       0.00

B-HI
      1980      6471.58     132917.1     0.000        0.00      0.0       0.00
      1990      9229.46     189560.1     0.000        0.00      0.0       0.00
E-LO
      1980      6123.11     125759.9     0.000        0.00      0.0       0.00
      1990      8024.05     164802.6     0.000        0.00      0.0       0.00

SELLER   28 - SUGAR

      1967        84.10         85.0     0.000        0.00      0.0       0.00

B-HI
      1980       116.32        117.6     0.000        0.00      0.0       0.00
      1990       165.89        167.7     0.000        0.00      0.0       0.00
E-LO
      1980       110.06        111.2     0.000        0.00      0.0       0.00
      1990       144.22        145.8     0.000        0.00      0.0       0.00

SELLER   49 - PAPER PROD, NEC

      1967       175.00        875.0     0.040       35.00      7.5     262.50

B-HI
      1980       242.04       1210.2     0.040       48.41      7.5     363.07
      1990       345.19       1726.0     0.040       69.04      7.5     517.79
E-LO
      1980       229.01       1145.1     0.040       45.80      7.5     343.52
      1990       300.11       1500.5     0.040       60.02      7.5     450.16

SELLER   74 - MISC PLSTC PRODS

      1967        52.00        106.0     0.000        0.00      0.0       0.00

B-HI
      1980        71.92        146.6     0.000        0.00      0.0       0.00
      1990       102.57        209.1     0.000        0.00      0.0       0.00
E-LO
      1980        68.05        138.7     0.000        0.00      0.0       0.00
      1990        89.18        181.8     0.000        0.00      0.0       0.00

TOTALS

      1967       4990.1      97166.0                  35.0               262.5

B-HI
      1980       6901.9     134391.5                  48.4               363.1
      1990       9843.1     191662.7                  69.0               517.8
E-LO
      1980       6530.2     127154.8                  45.8               343.5
      1990       8557.6     166630.6                  60.0               450.2
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BUYER    25 - CNND & FRZN F00DS                                              PAGE 1

                     D0LLARS       WEIGHT       W/C         WASTE       H/C          HEAT
                    MILLI0NS      MLN LBS                  MLN LBS                 BLN BTUS

SELLER    5 - GRAINS

    1967               96.05       3554.8     0.000          0.00       0.0          0.00

B-HI
    1980              159.82       5914.8     0.000          0.00       0.0          0.00
    1990              174.72       6466.5     0.000          0.00       0.0          0.00
E-L0
    1980              155.53       5756.3     0.000          0.00       0.0          0.00
    1990              159.11       5888.5     0.000          0.00       0.0          0.00

SELLER    7 - FRUIT & VEG

    1967             1337.10      44624.3     0.016        718.92       7.5       5391.89

B-HI
    1980             2224.79      74250.0     0.016       1196.20       7.5       8971.52
    1990             2432.30      81175.4     0.016       1307.78       7.5       9808.30
E-L0
    1980             2165.17      72260.5     0.016       1164.15       7.5       8731.12
    1990             2214.89      73919.7     0.016       1190.88       7.5       8931.61

SELLER    8 - FRSTRY & FSHRY PR0DS

    1967              508.78       2552.3     0.000          0.00       0.0          0.00

B-HI
    1980              846.55       4246.7     0.000          0.00       0.0          0.00
    1990              925.51       4642.8     0.000          0.00       0.0          0.00
E-L0
    1980              823.87       4132.9     0.000          0.00       0.0          0.00
    1990              842.79       4227.8     0.000          0.00       0.0          0.00

SELLER   23 - MEAT PR0DUCTS

    1967              239.40       1150.4     0.000          0.00       0.0          0.00

B-HI
    1980              398.34       1914.1     0.000          0.00       0.0          0.00
    1990              435.49       2092.7     0.000          0.00       0.0          0.00
E-L0
    1980              387.66       1862.8     0.000          0.00       0.0          0.00
    1990              396.56       1905.6     0.000          0.00       0.0          0.00

SELLER   25 - CNND & FRZN F00DS

    1967              142.46       1007.8     0.000          0.00       0.0          0.00

B-HI
    1980              237.04       1676.8     0.000          0.00       0.0          0.00
    1990              259.15       1833.2     0.000          0.00       0.0          0.00
E-L0
    1980              230.69       1631.9     0.000          0.00       0.0          0.00
    1990              235.98       1669.3     0.000          0.00       0.0          0.00
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ANDERSON JACOBSON, INC.

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BUYER    25 - CNND & FRZN FOODS                                         PAGE 2
                DOLLARS      WEIGHT      W/C        WASTE     H/C       HEAT
               MILLIONS     MLN LBS                MLN LBS            BLN BTUS

SELLER   26 - GRAIN MILL PRODUCTS

    1967          62.90        37.7    0.000          0.00    0.0        0.00

B-HI
    1980         104.66        62.7    0.000          0.00    0.0        0.00
    1990         114.42        68.6    0.000          0.00    0.0        0.00
E-LO
    1980         101.85        61.0    0.000          0.00    0.0        0.00
    1990         104.19        62.4    0.000          0.00    0.0        0.00

SELLER   28 - SUGAR

    1967         189.29      4166.6    0.000          0.00    0.0        0.00

B-HI
    1980         314.96      6932.7    0.000          0.00    0.0        0.00
    1990         344.33      7579.3    0.000          0.00    0.0        0.00
E-LO
    1980         306.52      6747.0    0.000          0.00    0.0        0.00
    1990         313.56      6901.9    0.000          0.00    0.0        0.00

SELLER   32 - FATS & OILS

    1967         156.00      1300.0    0.000          0.00    0.0        0.00

B-HI
    1980         259.57      2163.1    0.000          0.00    0.0        0.00
    1990         283.78      2364.8    0.000          0.00    0.0        0.00
E-LO
    1980         252.61      2105.1    0.000          0.00    0.0        0.00
    1990         258.41      2153.4    0.000          0.00    0.0        0.00

SELLER   49 - PAPER PROD, NEC

    1967         146.00       725.0    0.040         29.00    7.5      217.50

B-HI
    1980         242.93      1206.3    0.040         48.25    7.5      361.90
    1990         265.59      1318.8    0.040         52.75    7.5      395.65
E-LO
    1980         236.42      1174.0    0.040         46.96    7.5      352.20
    1990         241.85      1201.0    0.040         48.04    7.5      360.29

TOTALS

    1967         2878.0     59118.8                  747.9              5609.4

B-HI
    1980         4788.6     98367.2                 1244.5              9333.4
    1990         5235.3    107542.0                 1360.5             10204.0
E-LO
    1980         4660.3     95731.4                 1211.1              9083.3
    1990         4767.3     97929.6                 1238.9              9291.9

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BUYER     26 - GRAIN MILL PRØDUCTS                                              PAGE 1

                    DØLLARS        WEIGHT       W/C         WASTE       H/C        HEAT
                   MILLIØNS       MLN LBS                  MLN LBS                BLN BTUS

SELLER     5 - GRAINS

     1967          3190.23        98314.8     0.000          0.00       0.0         0.00

B-HI
     1980          4785.88       147488.7     0.000          0.00       0.0         0.00
     1990          5622.91       173283.8     0.000          0.00       0.0         0.00
E-LØ
     1980          4603.90       141880.5     0.000          0.00       0.0         0.00
     1990          5047.15       155540.4     0.000          0.00       0.0         0.00

SELLER    26 - GRAIN MILL PRØDUCTS

     1967           221.29         5708.8     0.000          0.00       0.0         0.00

B-HI
     1980           331.97         8564.1     0.000          0.00       0.0         0.00
     1990           390.03        10061.9     0.000          0.00       0.0         0.00
E-LØ
     1980           319.35         8238.5     0.000          0.00       0.0         0.00
     1990           350.10         9031.6     0.000          0.00       0.0         0.00

SELLER    28 - SUGAR

     1967           162.21         1712.2     0.000          0.00       0.0         0.00

B-HI
     1980           243.34         2568.6     0.000          0.00       0.0         0.00
     1990           285.90         3017.8     0.000          0.00       0.0         0.00
E-LØ
     1980           234.09         2470.9     0.000          0.00       0.0         0.00
     1990           256.63         2708.8     0.000          0.00       0.0         0.00

SELLER    32 - FATS & ØILS

     1967           875.40        19596.4     0.000          0.00       0.0         0.00

B-HI
     1980          1313.25        29397.8     0.000          0.00       0.0         0.00
     1990          1542.93        34539.4     0.000          0.00       0.0         0.00
E-LØ
     1980          1263.31        28280.0     0.000          0.00       0.0         0.00
     1990          1384.94        31002.7     0.000          0.00       0.0         0.00

SELLER    37 - MISC TEXTILES*

     1967            24.82           96.2     0.000          0.00       0.0         0.00

B-HI
     1980            37.23          144.3     0.000          0.00       0.0         0.00
     1990            43.75          169.5     0.000          0.00       0.0         0.00
E-LØ
     1980            35.82          138.8     0.000          0.00       0.0         0.00
     1990            39.27          152.1     0.000          0.00       0.0         0.00
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BUYER 26 - GRAIN MILL PRODUCTS

	DOLLARS MILLIONS	WEIGHT MLN LBS	W/C	WASTE MLN LBS	H/C	HEAT BLN BTUS
SELLER 40 - HOUSEHOLD TEXTILES*						
1967	108.14	567.4	0.000	0.00	0.0	0.00
B-HI						
1980	162.23	851.2	0.000	0.00	0.0	0.00
1990	190.60	1000.0	0.000	0.00	0.0	0.00
E-LO						
1980	156.06	818.8	0.000	0.00	0.0	0.00
1990	171.08	897.6	0.000	0.00	0.0	0.00
SELLER 49 - PAPER PROD, NEC						
1967	76.18	216.9	0.040	8.67	7.5	65.06
B-HI						
1980	114.28	325.3	0.040	13.01	7.5	97.60
1990	134.27	382.2	0.040	15.28	7.5	114.67
E-LO						
1980	109.94	313.0	0.040	12.51	7.5	93.89
1990	120.52	343.1	0.040	13.72	7.5	102.93
TOTALS						
1967	4658.3	126212.5		8.7		65.1
B-HI						
1980	6988.2	189339.9		13.0		97.6
1990	8210.4	222454.5		15.3		114.7
E-LO						
1980	6722.5	182140.3		12.5		93.9
1990	7369.7	199676.3		13.7		102.9

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BUYER    27 - BAKERY PRODUCTS

                     DOLLARS        WEIGHT       W/C         WASTE        H/C         HEAT
                     MILLIONS       MLN LBS                  MLN LBS                  BLN BTUS

SELLER   23 - MEAT PRODUCTS

      1967            107.80          518.0    0.000           0.00       0.0           0.00

B-HI
      1980            139.33          669.5    0.000           0.00       0.0           0.00
      1990            209.81         1008.2    0.000           0.00       0.0           0.00
E-LO
      1980            130.09          625.1    0.000           0.00       0.0           0.00
      1990            178.79          859.1    0.000           0.00       0.0           0.00

SELLER   24 - DAIRY PRODUCTS

      1967             44.18          231.5    0.000           0.00       0.0           0.00

B-HI
      1980             57.10          299.2    0.000           0.00       0.0           0.00
      1990             85.99          450.5    0.000           0.00       0.0           0.00
E-LO
      1980             53.31          279.3    0.000           0.00       0.0           0.00
      1990             73.27          383.9    0.000           0.00       0.0           0.00

SELLER   26 - GRAIN MILL PRODUCTS

      1967            894.34        14610.3    0.000           0.00       0.0           0.00

B-HI
      1980           1155.94        18883.9    0.000           0.00       0.0           0.00
      1990           1740.63        28435.7    0.000           0.00       0.0           0.00
E-LO
      1980           1079.24        17630.9    0.000           0.00       0.0           0.00
      1990           1483.30        24231.8    0.000           0.00       0.0           0.00

SELLER   28 - SUGAR

      1967            210.36         2210.1    0.000           0.00       0.0           0.00

B-HI
      1980            271.89         2856.6    0.000           0.00       0.0           0.00
      1990            409.42         4301.5    0.000           0.00       0.0           0.00
E-LO
      1980            253.85         2667.1    0.000           0.00       0.0           0.00
      1990            348.89         3665.6    0.000           0.00       0.0           0.00

SELLER   29 - CNFCTIONRY PRODUCTS

      1967             43.47           31.8    0.000           0.00       0.0           0.00

B-HI
      1980             56.19           41.1    0.000           0.00       0.0           0.00
      1990             84.60           61.8    0.000           0.00       0.0           0.00
E-LO
      1980             52.46           38.3    0.000           0.00       0.0           0.00
      1990             72.10           52.7    0.000           0.00       0.0           0.00
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ANDERSON JACOBSON, INC

BUYER 27 - BAKERY PRODUCTS

	DOLLARS MILLIONS	WEIGHT MLN LBS	W/C	WASTE MLN LBS	H/C	HEAT BLN BTUS
SELLER 32 - FATS & OILS						
1967	228.00	1520.0	0.036	54.72	12.5	684.00
B-HI						
1980	294.69	1964.6	0.036	70.73	12.5	884.07
1990	443.75	2958.3	0.036	106.50	12.5	1331.25
E-LO						
1980	275.14	1834.2	0.036	66.03	12.5	825.41
1990	378.15	2521.0	0.036	90.76	12.5	1134.44
SELLER 49 - PAPER PROD, NEC						
1967	197.00	985.0	0.040	39.40	7.5	295.50
B-HI						
1980	254.62	1273.1	0.040	50.92	7.5	381.93
1990	383.42	1917.1	0.040	76.68	7.5	575.12
E-LO						
1980	237.73	1188.6	0.040	47.55	7.5	356.59
1990	326.73	1633.7	0.040	65.35	7.5	490.10
SELLER 62 - PLSTC MATRLS & RESNS						
1967	72.00	617.0	0.022	13.57	12.5	169.67
B-HI						
1980	93.06	797.5	0.022	17.54	12.5	219.30
1990	140.13	1200.9	0.022	26.41	12.5	330.22
E-LO						
1980	86.89	744.6	0.022	16.38	12.5	204.75
1990	119.41	1023.3	0.022	22.51	12.5	281.40
TOTALS						
1967	1797.1	20723.7		107.7		1149.2
B-HI						
1980	2322.8	26785.5		139.2		1485.3
1990	3497.7	40334.0		209.6		2236.6
E-LO						
1980	2168.7	25008.2		130.0		1386.8
1990	2980.6	34371.1		178.6		1905.9

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BUYER     28 - SUGAR                                                      PAGE 1

                  DOLLARS      WEIGHT      W/C        WASTE       H/C       HEAT
                  MILLIONS     MLN LBS                MLN LBS               BLN BTUS

SELLER     7 - FRUIT & VEG

    1967          456.93       80388.3    0.000        0.00       0.0        0.00

B-HI
    1980          693.85      122069.8    0.000        0.00       0.0        0.00
    1990          842.49      148219.8    0.000        0.00       0.0        0.00
E-LO
    1980          665.33      117051.8    0.000        0.00       0.0        0.00
    1990          749.72      131898.7    0.000        0.00       0.0        0.00

SELLER    28 - SUGAR

    1967          985.22       13718.2    0.000        0.00       0.0        0.00

B-HI
    1980         1496.06       20831.2    0.000        0.00       0.0        0.00
    1990         1816.55       25293.6    0.000        0.00       0.0        0.00
E-LO
    1980         1434.56       19974.8    0.000        0.00       0.0        0.00
    1990         1616.52       22508.5    0.000        0.00       0.0        0.00

TOTALS

    1967          1442.1       94106.5                  0.0                  0.0

B-HI
    1980          2189.9      142900.9                  0.0                  0.0
    1990          2659.0      173513.4                  0.0                  0.0
E-LO
    1980          2099.9      137026.6                  0.0                  0.0
    1990          2366.2      154407.1                  0.0                  0.0
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BUYER     29 - CNFCTIONRY PRODUCTS                                           PAGE 1

                     DOLLARS      WEIGHT       W/C         WASTE       H/C        HEAT
                     MILLIONS     MLN LBS                  MLN LBS               BLN BTUS

SELLER     7 - FRUIT & VEG

     1967             192.89       833.0     0.000          0.00       0.0         0.00

B-HI
     1980             264.90      1144.1     0.000          0.00       0.0         0.00
     1990             289.43      1250.0     0.000          0.00       0.0         0.00
E-LO
     1980             254.98      1101.2     0.000          0.00       0.0         0.00
     1990             259.17      1119.3     0.000          0.00       0.0         0.00

SELLER    26 - GRAIN MILL PRODUCTS

     1967              72.00      1194.0     0.000          0.00       0.0         0.00

B-HI
     1980              98.88      1639.8     0.000          0.00       0.0         0.00
     1990             108.03      1791.6     0.000          0.00       0.0         0.00
E-LO
     1980              95.17      1578.3     0.000          0.00       0.0         0.00
     1990              96.74      1604.3     0.000          0.00       0.0         0.00

SELLER    28 - SUGAR

     1967             220.10      2230.4     0.000          0.00       0.0         0.00

B-HI
     1980             302.27      3063.1     0.000          0.00       0.0         0.00
     1990             330.26      3346.6     0.000          0.00       0.0         0.00
E-LO
     1980             290.94      2948.3     0.000          0.00       0.0         0.00
     1990             295.73      2996.7     0.000          0.00       0.0         0.00

SELLER    29 - CNFCTIONRY PRODUCTS

     1967             313.47      1003.0     0.000          0.00       0.0         0.00

B-HI
     1980             430.50      1377.5     0.000          0.00       0.0         0.00
     1990             470.36      1505.0     0.000          0.00       0.0         0.00
E-LO
     1980             414.37      1325.8     0.000          0.00       0.0         0.00
     1990             421.18      1347.6     0.000          0.00       0.0         0.00

TOTALS

     1967             798.5       5260.4                     0.0                    0.0

B-HI
     1980            1096.6       7224.3                     0.0                    0.0
     1990            1198.1       7893.2                     0.0                    0.0
E-LO
     1980            1055.5       6953.6                     0.0                    0.0
     1990            1072.8       7067.9                     0.0                    0.0
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BUYER    30 - ALCOHOLIC BEVERAGES                                    PAGE 1

                  DOLLARS      WEIGHT     W/C        WASTE      H/C       HEAT
                 MILLIONS     MLN LBS               MLN LBS              BLN BTUS

SELLER    5 - GRAINS

    1967          235.23      7542.9    0.000         0.00      0.0        0.00

B-HI
    1980          380.85     12212.3    0.000         0.00      0.0        0.00
    1990          432.84     13879.4    0.000         0.00      0.0        0.00
E-LO
    1980          389.88     12502.0    0.000         0.00      0.0        0.00
    1990          460.56     14768.3    0.000         0.00      0.0        0.00

SELLER    7 - FRUIT & VEG

    1967           75.35      3231.1    0.036       116.32      7.5      872.39

B-HI
    1980          122.00      5231.3    0.036       188.33      7.5     1412.44
    1990          138.65      5945.4    0.036       214.04      7.5     1605.25
E-LO
    1980          124.89      5355.4    0.036       192.79      7.5     1445.95
    1990          147.53      6326.2    0.036       227.74      7.5     1708.06

SELLER   26 - GRAIN MILL PRODUCTS

    1967           84.20      1396.0    0.000         0.00      0.0        0.00

B-HI
    1980          136.32      2260.2    0.000         0.00      0.0        0.00
    1990          154.93      2568.7    0.000         0.00      0.0        0.00
E-LO
    1980          139.56      2313.8    0.000         0.00      0.0        0.00
    1990          164.86      2733.2    0.000         0.00      0.0        0.00

SELLER   28 - SUGAR

    1967            2.50        37.4    0.000         0.00      0.0        0.00

B-HI
    1980            4.05        60.5    0.000         0.00      0.0        0.00
    1990            4.60        68.7    0.000         0.00      0.0        0.00
E-LO
    1980            4.14        61.9    0.000         0.00      0.0        0.00
    1990            4.89        73.1    0.000         0.00      0.0        0.00

SELLER   49 - PAPER PROD, NEC

    1967           72.00       292.0    0.040        11.68      7.5       87.60

B-HI
    1980          116.57       472.8    0.040        18.91      7.5      141.83
    1990          132.48       537.3    0.040        21.49      7.5      161.19
E-LO
    1980          119.34       484.0    0.040        19.36      7.5      145.19
    1990          140.97       571.7    0.040        22.87      7.5      171.51
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BUYER 30 - ALCOHOLIC BEVERAGES

	DOLLARS MILLIONS	WEIGHT MLN LBS	W/C	WASTE MLN LBS	H/C	HEAT BLN BTUS
TOTALS						
1967	469.3	12499.3		128.0		960.0
B-HI						
1980	759.8	20237.0		207.2		1554.3
1990	863.5	22999.6		235.5		1766.4
E-LO						
1980	777.8	20717.1		212.2		1591.1
1990	918.8	24472.6		250.6		1879.6

BUYER 31 - SFT DRNKS & FLVRNGS

	DOLLARS MILLIONS	WEIGHT MLN LBS	W/C	WASTE MLN LBS	H/C	HEAT BLN BTUS
SELLER 28 - SUGAR						
1967	361.29	3710.9	0.000	0.00	0.0	0.00
B-HI						
1980	582.55	5983.5	0.000	0.00	0.0	0.00
1990	653.49	6712.2	0.000	0.00	0.0	0.00
E-LO						
1980	558.65	5738.0	0.000	0.00	0.0	0.00
1990	578.27	5939.5	0.000	0.00	0.0	0.00
TOTALS						
1967	361.3	3710.9		0.0		0.0
B-HI						
1980	582.6	5983.5		0.0		0.0
1990	653.5	6712.2		0.0		0.0
E-LO						
1980	558.6	5738.0		0.0		0.0
1990	578.3	5939.5		0.0		0.0

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BUYER     32 - FATS & OILS                                                   PAGE 1

                      DOLLARS      WEIGHT       W/C        WASTE       H/C        HEAT
                      MILLIONS     MLN LBS                 MLN LBS               BLN BTUS
SELLER     4 - COTTON

     1967             287.09       7428.6     0.000         0.00       0.0        0.00

B-HI
     1980             433.99      11229.7     0.000         0.00       0.0        0.00
     1990             460.38      11912.6     0.000         0.00       0.0        0.00
E-LO
     1980             426.49      11035.7     0.000         0.00       0.0        0.00
     1990             427.34      11057.6     0.000         0.00       0.0        0.00

SELLER     5 - GRAINS

     1967            1532.87      32867.8     0.000         0.00       0.0        0.00

B-HI
     1980            2317.21      49685.7     0.000         0.00       0.0        0.00
     1990            2458.12      52707.1     0.000         0.00       0.0        0.00
E-LO
     1980            2277.18      48827.3     0.000         0.00       0.0        0.00
     1990            2281.69      48924.1     0.000         0.00       0.0        0.00

SELLER     7 - FRUIT & VEG

     1967            1083.66       3582.6     0.000         0.00       0.0        0.00

B-HI
     1980            1638.15       5415.8     0.000         0.00       0.0        0.00
     1990            1737.77       5745.1     0.000         0.00       0.0        0.00
E-LO
     1980            1609.85       5322.2     0.000         0.00       0.0        0.00
     1990            1613.04       5332.7     0.000         0.00       0.0        0.00

SELLER    23 - MEAT PRODUCTS

     1967             108.92       1211.6     0.000         0.00       0.0        0.00

B-HI
     1980             164.65       1831.6     0.000         0.00       0.0        0.00
     1990             174.67       1943.0     0.000         0.00       0.0        0.00
E-LO
     1980             161.81       1800.0     0.000         0.00       0.0        0.00
     1990             162.13       1803.5     0.000         0.00       0.0        0.00

TOTALS

     1967             3012.5      45090.7                   0.0                   0.0

B-HI
     1980             4554.0      68162.7                   0.0                   0.0
     1990             4830.9      72307.8                   0.0                   0.0
E-LO
     1980             4475.3      66985.1                   0.0                   0.0
     1990             4484.2      67117.9                   0.0                   0.0
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BUYER     33 - MISC FOOD PRODUCTS
                                                                                PAGE 1
                 DOLLARS         WEIGHT        W/C        WASTE       H/C        HEAT
                 MILLIONS        MLN LBS                  MLN LBS                BLN BTUS
SELLER     3 - MEAT,MISC LVSTK PRD*

      1967        67.50          324.4       0.000        0.00       0.0         0.00

B-HI
      1980        90.31          434.0       0.000        0.00       0.0         0.00
      1990       104.79          503.6       0.000        0.00       0.0         0.00
E-LO
      1980        85.77          412.2       0.000        0.00       0.0         0.00
      1990        98.75          474.6       0.000        0.00       0.0         0.00
SELLER     7 - FRUIT & VEG

      1967       195.42         4256.6       0.011       48.06       7.5       360.43

B-HI
      1980       261.47         5695.2       0.011       64.30       7.5       482.25
      1990       303.39         6608.4       0.011       74.61       7.5       559.57
E-LO
      1980       248.33         5409.0       0.011       61.07       7.5       458.01
      1990       285.90         6227.5       0.011       70.31       7.5       527.31
SELLER    26 - GRAIN MILL PRODUCTS

      1967        72.90          969.9       0.000        0.00       0.0         0.00

B-HI
      1980        97.54         1297.7       0.000        0.00       0.0         0.00
      1990       113.18         1505.8       0.000        0.00       0.0         0.00
E-LO
      1980        92.64         1232.5       0.000        0.00       0.0         0.00
      1990       106.65         1419.0       0.000        0.00       0.0         0.00
SELLER    27 - BAKERY PRODUCTS

      1967        59.20          270.3       0.000        0.00       0.0         0.00

B-HI
      1980        79.21          361.7       0.000        0.00       0.0         0.00
      1990        91.91          419.6       0.000        0.00       0.0         0.00
E-LO
      1980        75.23          343.5       0.000        0.00       0.0         0.00
      1990        86.61          395.5       0.000        0.00       0.0         0.00
SELLER    28 - SUGAR

      1967        61.20          624.3       0.000        0.00       0.0         0.00

B-HI
      1980        81.88          835.3       0.000        0.00       0.0         0.00
      1990        95.01          969.2       0.000        0.00       0.0         0.00
E-LO
      1980        77.77          793.3       0.000        0.00       0.0         0.00
      1990        89.54          913.4       0.000        0.00       0.0         0.00
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ANDERSON JACOBSON, INC.

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BUYER    33 - MISC FOOD PRODUCTS                                        PAGE 2

                  DOLLARS       WEIGHT      W/C        WASTE      H/C       HEAT
                  MILLIONS      MLN LBS                MLN LBS              BLN BTUS
SELLER   32 - FATS & OILS

     1967          91.68        564.6     0.036        20.33     12.5      254.09

B-HI
     1980         122.67        755.5     0.036        27.20     12.5      339.97
     1990         142.33        876.6     0.036        31.56     12.5      394.47
E-L0
     1980         116.50        717.5     0.036        25.83     12.5      322.88
     1990         134.13        826.1     0.036        29.74     12.5      371.74

SELLER   49 - PAPER PROD, NEC

     1967          63.00        254.0     0.040        10.16      7.5       76.20

B-HI
     1980          84.29        339.8     0.040        13.59      7.5      101.95
     1990          97.81        394.3     0.040        15.77      7.5      118.30
E-L0
     1980          80.06        322.8     0.040        12.91      7.5       96.83
     1990          92.17        371.6     0.040        14.86      7.5      111.48

TOTALS

     1967          610.9       7264.1                   78.5                690.7

B-HI
     1980          817.4       9719.3                  105.1                924.2
     1990          948.4      11277.6                  121.9               1072.3
E-L0
     1980          776.3       9230.8                   99.8                877.7
     1990          893.8      10627.5                  114.9               1010.5
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BUYER 34 - TOBACCO PRODUCTS PAGE 1

	DOLLARS MILLIONS	WEIGHT MLN LBS	W/C	WASTE MLN LBS	H/C	HEAT BLN BTUS
SELLER 6 - TOBACCO						
1967	94.85	104.5	0.000	0.00	0.0	0.00
B-HI						
1980	141.00	155.4	0.000	0.00	0.0	0.00
1990	192.19	211.8	0.000	0.00	0.0	0.00
E-LO						
1980	142.39	156.9	0.000	0.00	0.0	0.00
1990	189.29	208.6	0.000	0.00	0.0	0.00
SELLER 34 - TOBACCO PRODUCTS						
1967	2166.01	2804.2	0.004	11.23	7.5	84.13
B-HI						
1980	3219.95	4168.7	0.004	16.69	7.5	125.07
1990	4388.87	5682.0	0.004	22.75	7.5	170.47
E-LO						
1980	3251.66	4209.8	0.004	16.86	7.5	126.30
1990	4322.61	5596.3	0.004	22.41	7.5	167.89
SELLER 62 - PLSTC MATRLS & RESNS						
1967	108.37	679.5	0.022	15.11	12.5	188.61
B-HI						
1980	161.10	1010.2	0.022	22.46	12.5	280.38
1990	219.58	1376.9	0.022	30.62	12.5	382.17
E-LO						
1980	162.69	1020.1	0.022	22.68	12.5	283.15
1990	216.27	1356.1	0.022	30.15	12.5	376.40
TOTALS						
1967	2369.2	3588.3		26.3		272.7
B-HI						
1980	3522.0	5334.2		39.2		405.4
1990	4800.6	7270.7		53.4		552.6
E-LO						
1980	3556.7	5386.8		39.5		409.4
1990	4728.2	7161.0		52.6		544.3

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BUYER     35 - BRØAD & NARRØW FBRCS                                          PAGE 1

                DØLLARS        WEIGHT        W/C         WASTE        H/C        HEAT
                MILLIØNS       MLN LBS                   MLN LBS                 BLN BTUS

SELLER     4 - CØTTØN

     1967       1237.76        4522.5       0.001         4.52        7.5        33.91

B-HI
     1980       2283.16        8342.2       0.001         8.34        7.5        62.55
     1990       3396.36       12409.6       0.001        12.40        7.5        93.05
E-LØ
     1980       2122.25        7754.3       0.001         7.75        7.5        58.14
     1990       2770.75       10123.8       0.001        10.12        7.5        75.91

SELLER    12 - WØØL PRØCESSØRS*

     1967        497.13         462.4       0.020         9.25        7.5        69.35

B-HI
     1980        917.00         852.9       0.020        17.06        7.5       127.92
     1990       1364.10        1268.8       0.020        25.38        7.5       190.29
E-LØ
     1980        852.37         792.8       0.020        15.86        7.5       118.91
     1990       1112.84        1035.0       0.020        20.71        7.5       155.24

SELLER    35 - BRØAD & NARRØW FBRCS

     1967       1428.60        1768.4       0.020        35.38       10.0       353.68

B-HI
     1980       2635.19        3262.0       0.020        65.26       10.0       652.40
     1990       3920.02        4852.4       0.020        97.08       10.0       970.48
E-LØ
     1980       2449.46        3032.1       0.020        60.66       10.0       606.42
     1990       3197.96        3958.6       0.020        79.20       10.0       791.72

SELLER    49 - PAPER PRØD, NEC

     1967         69.00         278.0       0.000         0.00        0.0         0.00

B-HI
     1980        127.28         512.8       0.000         0.00        0.0         0.00
     1990        189.33         762.8       0.000         0.00        0.0         0.00
E-LØ
     1980        118.31         476.7       0.000         0.00        0.0         0.00
     1990        154.46         622.3       0.000         0.00        0.0         0.00

SELLER    62 - PLSTC MATRLS & RESNS

     1967         14.47          25.3       0.001         0.03       10.7         0.32

B-HI
     1980         26.69          46.7       0.001         0.06       10.7         0.59
     1990         39.71          69.5       0.001         0.08       10.7         0.88
E-LØ
     1980         24.81          43.4       0.001         0.05       10.7         0.55
     1990         32.39          56.7       0.001         0.07       10.7         0.72
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BUYER 35 - BROAD & NARROW FBRCS

	DOLLARS MILLIONS	WEIGHT MLN LBS	W/C	WASTE MLN LBS	H/C	HEAT BLN BTUS
SELLER 64 - CELLULOSIC FIBERS						
1967	500.86	1004.6	0.001	1.01	12.4	12.56
B-HI						
1980	923.88	1853.2	0.001	1.86	12.4	23.17
1990	1374.34	2756.7	0.001	2.77	12.4	34.46
E-LO						
1980	858.77	1722.6	0.001	1.73	12.4	21.54
1990	1121.19	2248.9	0.001	2.26	12.4	28.12
SELLER 65 - NON-CELLULOSIC FBRS						
1967	1249.34	1398.1	0.001	1.40	12.5	17.45
B-HI						
1980	2304.52	2578.9	0.001	2.58	12.5	32.19
1990	3428.13	3836.4	0.001	3.84	12.5	47.88
E-LO						
1980	2142.10	2397.2	0.001	2.40	12.5	29.92
1990	2796.68	3129.7	0.001	3.13	12.5	39.06
TOTALS						
1967	4997.2	9459.4		51.6		487.3
B-HI						
1980	9217.7	17448.7		95.2		898.8
1990	13712.0	25956.1		141.6		1337.0
E-LO						
1980	8568.1	16218.9		88.5		835.5
1990	11186.3	21175.0		115.5		1090.8

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BUYER    36 - FLØØR CØVERINGS                                          PAGE 1

                  DØLLARS      WEIGHT      W/C        WASTE      H/C        HEAT
                 MILLIØNS     MLN LBS                MLN LBS               BLN BTUS

SELLER   35 - BRØAD & NARRØW FBRCS

     1967         838.80        718.8    0.020         14.38      8.7        124.92

B-HI
     1980        2073.85       1777.3    0.020         35.55      8.7        308.85
     1990        2733.74       2342.8    0.020         46.87      8.7        407.13
E-LØ
     1980        1722.85       1476.5    0.020         29.54      8.7        256.58
     1990        1712.29       1467.4    0.020         29.35      8.7        255.01

SELLER   37 - MISC TEXTILES*

     1967          71.80        392.4    0.020          7.85      7.5         58.85

B-HI
     1980         177.52        970.2    0.020         19.41      7.5        145.50
     1990         234.00       1278.9    0.020         25.58      7.5        191.80
E-LØ
     1980         147.47        806.0    0.020         16.12      7.5        120.87
     1990         146.57        801.0    0.020         16.02      7.5        120.13

SELLER   49 - PAPER PRØD, NEC

     1967          57.00        287.0    0.000          0.00      0.0          0.00

B-HI
     1980         140.93        709.6    0.000          0.00      0.0          0.00
     1990         185.77        935.4    0.000          0.00      0.0          0.00
E-LØ
     1980         117.08        589.5    0.000          0.00      0.0          0.00
     1990         116.36        585.9    0.000          0.00      0.0          0.00

SELLER   65 - NØN-CELLULØSIC FBRS

     1967         470.00        259.0    0.001          0.26     12.5          3.24

B-HI
     1980        1162.03        640.4    0.001          0.64     12.5          8.01
     1990        1531.78        844.1    0.001          0.85     12.5         10.56
E-LØ
     1980         965.36        532.0    0.001          0.53     12.5          6.65
     1990         959.44        528.7    0.001          0.53     12.5          6.61

TØTALS

     1967         1437.6       1657.2                   22.5                  187.0

B-HI
     1980         3554.3       4097.4                   55.6                  462.4
     1990         4685.3       5401.2                   73.3                  609.5
E-LØ
     1980         2952.8       3403.9                   46.2                  384.1
     1990         2934.7       3383.0                   45.9                  381.8

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BUYER 37 - MISC TEXTILES*

	DOLLARS MILLIONS	WEIGHT MLN LBS	W/C	WASTE MLN LBS	H/C	HEAT BLN BTUS
SELLER 12 - WOOL PROCESSORS*						
1967	22.50	81.4	0.020	1.63	7.5	12.22
B-HI						
1980	37.26	134.8	0.020	2.70	7.5	20.24
1990	55.08	199.3	0.020	3.99	7.5	29.92
E-LO						
1980	34.68	125.5	0.020	2.51	7.5	18.83
1990	46.48	168.2	0.020	3.37	7.5	25.24
SELLER 35 - BROAD & NARROW FBRCS						
1967	239.15	343.6	0.040	13.74	9.6	131.33
B-HI						
1980	396.08	569.1	0.040	22.76	9.6	217.51
1990	585.47	841.2	0.040	33.64	9.6	321.51
E-LO						
1980	368.59	529.6	0.040	21.18	9.6	202.41
1990	494.02	709.8	0.040	28.38	9.6	271.29
SELLER 40 - HOUSEHOLD TEXTILES*						
1967	109.50	187.2	0.040	7.49	10.0	74.89
B-HI						
1980	181.35	310.1	0.040	12.40	10.0	124.03
1990	268.07	458.3	0.040	18.34	10.0	183.34
E-LO						
1980	168.77	288.6	0.040	11.54	10.0	115.42
1990	226.20	386.7	0.040	15.47	10.0	154.70
SELLER 62 - PLSTC MATRLS & RESNS						
1967	97.96	290.0	0.018	5.13	12.5	64.13
B-HI						
1980	162.24	480.3	0.018	8.50	12.5	106.21
1990	239.82	710.0	0.018	12.56	12.5	157.00
E-LO						
1980	150.98	447.0	0.018	7.91	12.5	98.84
1990	202.36	599.1	0.018	10.60	12.5	132.48
SELLER 64 - CELLULOSIC FIBERS						
1967	4.85	4.9	0.000	0.00	0.0	0.06
B-HI						
1980	8.03	8.0	0.000	0.00	0.0	0.10
1990	11.87	11.9	0.000	0.00	0.0	0.15
E-LO						
1980	7.48	7.5	0.000	0.00	0.0	0.09
1990	10.02	10.0	0.000	0.00	0.0	0.12

	DOLLARS MILLIONS	WEIGHT MLN LBS	W/C	WASTE MLN LBS	H/C	HEAT BLN BTUS
TOTALS						
1967	474.0	907.1		28.0		282.6
B-HI						
1980	785.0	1502.3		46.4		468.1
1990	1160.3	2220.7		68.5		691.9
E-LO						
1980	730.5	1398.1		43.1		435.6
1990	979.1	1873.8		57.8		583.8

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BUYER     38 - KNITTING                                                    PAGE 1

                    DOLLARS         WEIGHT       W/C         WASTE       H/C         HEAT
                   MILLIONS        MLN LBS                  MLN LBS                BLN BTUS

SELLER    35 - BROAD & NARROW FBRCS

     1967          809.32          710.8      0.040          28.42       9.8       279.07

B-HI
     1980         1596.74         1402.4      0.040          56.07       9.8       550.59
     1990         1987.47         1745.6      0.040          69.79       9.8       685.32
E-LO
     1980         1695.99         1489.6      0.040          59.56       9.8       584.81
     1990         1848.17         1623.3      0.040          64.90       9.8       637.29

SELLER    38 - KNITTING

     1967           85.67          123.4      0.040           4.94      10.0        49.37

B-HI
     1980          169.02          243.5      0.040           9.75      10.0        97.40
     1990          210.38          303.1      0.040          12.13      10.0       121.24
E-LO
     1980          179.53          258.7      0.040          10.35      10.0       103.46
     1990          195.64          281.9      0.040          11.28      10.0       112.74

SELLER    64 - CELLULOSIC FIBERS

     1967          132.57          159.3      0.001           0.16      12.4         1.99

B-HI
     1980          261.55          314.3      0.001           0.32      12.4         3.93
     1990          325.56          391.2      0.001           0.39      12.4         4.89
E-LO
     1980          277.81          333.8      0.001           0.34      12.4         4.17
     1990          302.74          363.8      0.001           0.37      12.4         4.54

SELLER    65 - NON-CELLULOSIC FBRS

     1967          198.16           79.6      0.001           0.09      11.1         1.00

B-HI
     1980          390.96          157.0      0.001           0.18      11.1         1.97
     1990          486.63          195.4      0.001           0.22      11.1         2.46
E-LO
     1980          415.26          166.8      0.001           0.19      11.1         2.10
     1990          452.52          181.7      0.001           0.21      11.1         2.28

TOTALS

     1967          1225.7         1073.2                      33.6                 331.4

B-HI
     1980          2418.3         2117.3                      66.3                 653.9
     1990          3010.0         2635.4                      82.5                 813.9
E-LO
     1980          2568.6         2248.9                      70.4                 694.5
     1990          2799.1         2450.7                      76.8                 756.9
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BUYER     39 - APPAREL                                                          PAGE 1

                  DOLLARS       WEIGHT      W/C        WASTE       H/C       HEAT
                  MILLIONS      MLN LBS                MLN LBS               BLN BTUS

SELLER    35 - BROAD & NARROW FBRCS

     1967         4320.63       4423.4     0.040      176.92      7.6      1340.98

B-HI
     1980         7503.09       7681.6     0.040      307.23      7.6      2328.71
     1990        10854.91      11113.1     0.040      444.48      7.6      3369.00
E-LO
     1980         6861.03       7024.2     0.040      280.94      7.6      2129.43
     1990         8807.01       9016.5     0.040      360.63      7.6      2733.40

SELLER    37 - MISC TEXTILES*

     1967           56.70        340.0     0.040       13.60     12.5       170.00

B-HI
     1980           98.46        590.4     0.040       23.62     12.5       295.22
     1990          142.45        854.2     0.040       34.17     12.5       427.10
E-LO
     1980           90.04        539.9     0.040       21.60     12.5       269.95
     1990          115.58        693.0     0.040       27.72     12.5       346.52

SELLER    38 - KNITTING

     1967          994.45        966.0     0.040       38.64     10.0       386.39

B-HI
     1980         1726.94       1677.5     0.040       67.10     10.0       670.99
     1990         2498.40       2426.9     0.040       97.08     10.0       970.74
E-LO
     1980         1579.16       1534.0     0.040       61.36     10.0       613.58
     1990         2027.05       1969.0     0.040       78.76     10.0       787.60

SELLER    40 - HOUSEHOLD TEXTILES*

     1967          327.72       1568.9     0.040       62.76     10.0       627.54

B-HI
     1980          569.11       2724.5     0.040      108.99     10.0      1089.77
     1990          823.35       3941.5     0.040      157.67     10.0      1576.60
E-LO
     1980          520.41       2491.3     0.040       99.66     10.0       996.51
     1990          668.01       3197.9     0.040      127.93     10.0      1279.15

SELLER    73 - RUBBER PRODUCTS

     1967           16.00         16.0     0.050        0.80     10.0         8.00

B-HI
     1980           27.79         27.8     0.050        1.39     10.0        13.89
     1990           40.20         40.2     0.050        2.01     10.0        20.10
E-LO
     1980           25.41         25.4     0.050        1.27     10.0        12.70
     1990           32.61         32.6     0.050        1.63     10.0        16.31
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BUYER 39 - APPAREL

	DOLLARS MILLIONS	WEIGHT MLN LBS	W/C	WASTE MLN LBS	H/C	HEAT BLN BTUS
SELLER 75 - LTHR TAN & INDS LTHR						
1967	67.24	20.8	0.000	0.00	0.0	0.00
B-HI						
1980	116.77	36.1	0.000	0.00	0.0	0.00
1990	168.93	52.2	0.000	0.00	0.0	0.00
E-LO						
1980	106.78	33.0	0.000	0.00	0.0	0.00
1990	137.06	42.3	0.000	0.00	0.0	0.00
TOTALS						
1967	5782.7	7335.0		292.7		2532.9
B-HI						
1980	10042.2	12737.8		508.3		4398.6
1990	14528.2	18428.1		735.4		6363.5
E-LO						
1980	9182.8	11647.8		464.8		4022.2
1990	11787.3	14951.4		596.7		5163.0

BUYER 40 - HOUSEHOLD TEXTILES*

	DOLLARS MILLIONS	WEIGHT MLN LBS	W/C	WASTE MLN LBS	H/C	HEAT BLN BTUS
SELLER 4 - COTTON						
1967	13.30	51.5	0.001	0.05	7.8	0.39
B-HI						
1980	22.22	86.1	0.001	0.08	7.8	0.65
1990	32.23	124.9	0.001	0.12	7.8	0.95
E-LO						
1980	21.45	83.1	0.001	0.08	7.8	0.63
1990	28.75	111.4	0.001	0.11	7.8	0.84
SELLER 35 - BROAD & NARROW FBRCS						
1967	728.05	1429.0	0.039	55.77	8.3	464.41
B-HI						
1980	1216.27	2387.2	0.039	93.17	8.3	775.83
1990	1764.48	3463.2	0.039	135.16	8.3	1125.53
E-LO						
1980	1174.24	2304.7	0.039	89.95	8.3	749.02
1990	1573.87	3089.1	0.039	120.56	8.3	1003.95
SELLER 37 - MISC TEXTILES*						
1967	383.62	950.2	0.040	38.01	7.5	285.07
B-HI						
1980	640.87	1587.4	0.040	63.50	7.5	476.23
1990	929.73	2303.0	0.040	92.12	7.5	690.89
E-LO						
1980	618.72	1532.6	0.040	61.30	7.5	459.78
1990	829.30	2054.2	0.040	82.17	7.5	616.25
SELLER 64 - CELLULOSIC FIBERS						
1967	72.72	159.5	0.013	2.09	12.5	26.15
B-HI						
1980	121.48	266.5	0.013	3.49	12.5	43.69
1990	176.24	386.7	0.013	5.07	12.5	63.38
E-LO						
1980	117.29	257.3	0.013	3.37	12.5	42.18
1990	157.20	344.9	0.013	4.52	12.5	56.53
SELLER 65 - NON-CELLULOSIC FBRS						
1967	256.00	312.0	0.001	0.31	12.6	3.90
B-HI						
1980	427.67	521.2	0.001	0.52	12.6	6.52
1990	620.43	756.2	0.001	0.75	12.6	9.45
E-LO						
1980	412.89	503.2	0.001	0.50	12.6	6.29
1990	553.41	674.5	0.001	0.67	12.6	8.43

BUYER 40 - HOUSEHOLD TEXTILES*

	DOLLARS MILLIONS	WEIGHT MLN LBS	W/C	WASTE MLN LBS	H/C	HEAT BLN BTUS
SELLER 74 - MISC PLSTC PRODS						
1967	22.40	60.1	0.011	0.66	12.5	8.26
B-HI						
1980	37.42	100.4	0.011	1.10	12.5	13.80
1990	54.29	145.7	0.011	1.60	12.5	20.02
E-LO						
1980	36.13	96.9	0.011	1.06	12.5	13.32
1990	48.42	129.9	0.011	1.43	12.5	17.86
TOTALS						
1967	1476.1	2962.4		96.9		788.2
B-HI						
1980	2465.9	4948.9		161.9		1316.7
1990	3577.4	7179.6		234.8		1910.2
E-LO						
1980	2380.7	4777.9		156.3		1271.2
1990	3191.0	6404.0		209.5		1703.9

BUYER 41 - LMBR & W00D PR0DUCTS

	D0LLARS MILLI0NS	WEIGHT MLN LBS	W/C	WASTE MLN LBS	H/C	HEAT BLN BTUS
SELLER 8 - FRSTRY & FSHRY PR0DS						
1967	13202.00	264037.0	0.085	22443.20	10.0	224432.00
B-HI						
1980	23421.59	468426.6	0.042	19908.18	10.0	199081.80
1990	32006.84	640129.6	0.042	27205.60	10.0	
E-L0						
1980	21429.67	428588.5	0.021	18215.05	10.0	182150.5
1990	26739.65	534786.9	0.021	22728.50	10.0	227285.0
SELLER 41 - LMBR & W00D PR0DUCTS						
1967	1241.94	94512.8	0.051	4774.21	10.0	47742.02
B-HI						
1980	2203.32	167674.7	0.025	4234.95	10.0	42349.50
1990	3010.95	229136.3	0. 25	5782.28	10.0	57822.81
E-L0						
1980	2015.93	153414.5	0.012	3874.80	10.0	38748.03
1990	2515.46	191428.6	0.012	4834.90	10.0	48349.07
T0TALS						
1967	14443.9	358549.8		27217.4		272174.0
B-HI						
1980	25624.9	636101.3		24143.2		241432.07
1990	35017.8	869265.9		32992.8		329928.53
E-L0						
1980	23445.6	582003.0		22089.9		220899.31
1990	29255.1	726215.4		27563.4		275634.16

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BUYER     42 - VENEER & PLYWØØD                                                        PAGE 1

                    DØLLARS       WEIGHT       W/C        WASTE        H/C         HEAT
                   MILLIØNS      MLN LBS                 MLN LBS                 BLN BTUS

SELLER    41 - LMBR & WØØD PRØDUCTS

     1967           296.71       22760.6      0.050       1148.87      10.0      11488.61

B-HI
     1980           516.88       39649.9      0.050       2001.38      10.0      20013.66
     1990           777.23       59621.3      0.050       3009.46      10.0      30094.40
E-LØ
     1980           472.24       36225.4      0.050       1828.53      10.0      18285.11
     1990           646.84       49618.9      0.050       2504.58      10.0      25045.53

SELLER    42 - VENEER & PLYWØØD

     1967           369.10        5098.4      0.020        101.97      10.0       1019.68

B-HI
     1980           642.99        8881.7      0.020        177.64      10.0       1776.33
     1990           966.86       13355.3      0.020        267.11      10.0       2671.05
E-LØ
     1980           587.45        8114.6      0.020        162.29      10.0       1622.91
     1990           804.65       11114.8      0.020        222.30      10.0       2222.94

SELLER    43 - MILLWØRK & WØØD PRØD

     1967             6.12          98.7      0.050          4.93      10.0         49.35

B-HI
     1980            10.66         171.9      0.050          8.59      10.0         85.97
     1990            16.03         258.5      0.050         12.91      10.0        129.27
E-LØ
     1980             9.74         157.1      0.050          7.85      10.0         78.54
     1990            13.34         215.2      0.050         10.75      10.0        107.58

TØTALS

     1967            671.9       27957.7                  1255.8                 12557.6

B-HI
     1980           1170.5       48703.5                  2187.6                 21875.9
     1990           1760.1       73235.2                  3289.5                 32894.7
E-LØ
     1980           1069.4       44497.1                  1998.7                 19986.6
     1990           1464.8       60948.8                  2737.6                 27376.1
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BUYER     43 - MILLWORK & WOOD PROD                                          PAGE 1

                DOLLARS      WEIGHT      W/C        WASTE      H/C        HEAT
                MILLIONS     MLN LBS                MLN LBS              BLN BTUS

SELLER    41 - LMBR & WOOD PRODUCTS

    1967        854.16      45536.7     0.042      1896.84     10.0     18968.29

B-HI
    1980       1404.58      74880.4     0.042      3119.15     10.0     31191.36
    1990       1995.35     106375.8     0.042      4431.10     10.0     44310.73
E-LO
    1980       1288.60      68697.3     0.042      2861.60     10.0     28615.81
    1990       1667.00      88870.7     0.042      3701.92     10.0     37019.00

SELLER    42 - VENEER & PLYWOOD

    1967        157.85       1081.0     0.030        32.76     10.0       327.54

B-HI
    1980        259.57       1777.7     0.030        53.87     10.0       538.61
    1990        368.74       2525.4     0.030        76.53     10.0       765.15
E-LO
    1980        238.13       1630.9     0.030        49.42     10.0       494.13
    1990        308.06       2109.8     0.030        63.94     10.0       639.24

SELLER    43 - MILLWORK & WOOD PROD

    1967         16.16        237.5     0.050        11.87     10.0       118.74

B-HI
    1980         26.57        390.5     0.050        19.52     10.0       195.26
    1990         37.75        554.7     0.050        27.73     10.0       277.38
E-LO
    1980         24.38        358.3     0.050        17.91     10.0       179.13
    1990         31.54        463.5     0.050        23.17     10.0       231.74

TOTALS

    1967        1028.2      46855.3                 1941.5               19414.6

B-HI
    1980        1690.7      77048.5                 3192.5               31925.2
    1990        2401.8     109455.9                 4535.4               45353.3
E-LO
    1980        1551.1      70686.5                 2928.9               29289.1
    1990        2006.6      91443.9                 3789.0               37890.0
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BUYER     44 - WOODEN CONTAINERS                                                PAGE 1

                    DOLLARS        WEIGHT       W/C        WASTE       H/C        HEAT
                   MILLIONS       MLN LBS                 MLN LBS                BLN BTUS

SELLER    41 - LMBR & WOOD PRODUCTS

     1967          106.00         6183.3      0.045        277.89      10.0      2779.12

B-HI
     1980          148.87         8683.9      0.045        390.28      10.0      3903.08
     1990          199.05        11610.9      0.045        521.82      10.0      5218.61
E-LO
     1980          141.19         8235.7      0.045        370.13      10.0      3701.62
     1990          174.49        10178.4      0.045        457.44      10.0      4574.78

SELLER    42 - VENEER & PLYWOOD

     1967           24.60          376.0      0.029         10.92      10.0       109.21

B-HI
     1980           34.55          528.0      0.029         15.34      10.0       153.38
     1990           46.19          706.0      0.029         20.51      10.0       205.07
E-LO
     1980           32.77          500.8      0.029         14.54      10.0       145.46
     1990           40.49          618.9      0.029         17.98      10.0       179.77

TOTALS

     1967          130.6          6559.2                   288.8                 2888.3

B-HI
     1980          183.4          9212.0                   405.6                 4056.5
     1990          245.2         12316.9                   542.3                 5423.7
E-LO
     1980          174.0          8736.5                   384.7                 3847.1
     1990          215.0         10797.3                   475.4                 4754.6
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BUYER 45 - HOUSEHOLD FURNITURE

	DOLLARS MILLIONS	WEIGHT MLN LBS	W/C	WASTE MLN LBS	H/C	HEAT BLN BTUS
SELLER 32 - FATS & OILS						
1967	34.42	342.1	0.025	8.55	12.5	106.92
B-HI						
1980	70.63	702.1	0.025	17.54	12.5	219.40
1990	139.63	1388.0	0.025	34.68	12.5	433.74
E-LO						
1980	60.86	604.9	0.025	15.12	12.5	189.05
1990	106.91	1062.7	0.025	26.56	12.5	332.11
SELLER 35 - BROAD & NARROW FBRCS						
1967	220.15	119.4	0.040	4.78	8.5	40.58
B-HI						
1980	451.75	245.1	0.040	9.81	8.5	83.27
1990	893.08	484.6	0.040	19.39	8.5	164.62
E-LO						
1980	389.25	211.2	0.040	8.45	8.5	71.75
1990	683.82	371.0	0.040	14.85	8.5	126.05
SELLER 37 - MISC TEXTILES*						
1967	26.46	15.1	0.040	0.60	7.6	4.53
B-HI						
1980	54.30	31.0	0.040	1.23	7.6	9.30
1990	107.34	61.3	0.040	2.43	7.6	18.38
E-LO						
1980	46.78	26.7	0.040	1.06	7.6	8.01
1990	82.19	46.9	0.040	1.86	7.6	14.07
SELLER 40 - HOUSEHOLD TEXTILES*						
1967	79.58	402.5	0.040	16.10	7.5	120.76
B-HI						
1980	163.30	825.9	0.040	33.04	7.5	247.80
1990	322.83	1632.7	0.040	65.31	7.5	489.88
E-LO						
1980	140.71	711.6	0.040	28.47	7.5	213.52
1990	247.19	1250.1	0.040	50.01	7.5	375.10
SELLER 41 - LMBR & WOOD PRODUCTS						
1967	428.39	11438.3	0.059	669.85	10.0	6698.50
B-HI						
1980	879.06	23471.6	0.059	1374.54	10.0	13745.40
1990	1737.84	46401.6	0.059	2717.37	10.0	27173.67
E-LO						
1980	757.44	20224.3	0.059	1184.37	10.0	11843.71
1990	1330.65	35529.5	0.059	2080.67	10.0	20806.71

BUYER 45 - HOUSEHOLD FURNITURE

	DOLLARS MILLIONS	WEIGHT MLN LBS	W/C	WASTE MLN LBS	H/C	HEAT BLN BTUS
SELLER 42 - VENEER & PLYWOOD						
1967	184.32	875.6	0.044	38.46	10.0	384.57
B-HI						
1980	378.23	1796.8	0.044	78.92	10.0	789.14
1990	747.73	3552.1	0.044	156.02	10.0	1560.08
E-L0						
1980	325.90	1548.2	0.044	68.00	10.0	679.96
1990	572.53	2719.8	0.044	119.46	10.0	1194.54
SELLER 43 - MILLWORK & WOOD PROD						
1967	53.30	745.9	0.050	37.30	10.0	372.95
B-HI						
1980	109.37	1530.6	0.050	76.54	10.0	765.30
1990	216.22	3025.9	0.050	151.31	10.0	1512.94
E-L0						
1980	94.24	1318.9	0.050	65.95	10.0	659.42
1990	165.56	2316.9	0.050	115.86	10.0	1158.45
SELLER 68 - PAINTS						
1967	71.19	260.7	0.000	0.00	0.0	0.00
B-HI						
1980	146.08	535.0	0.000	0.00	0.0	0.00
1990	288.79	1057.7	0.000	0.00	0.0	0.00
E-L0						
1980	125.87	461.0	0.000	0.00	0.0	0.00
1990	221.13	809.9	0.000	0.00	0.0	0.00
SELLER 73 - RUBBER PRODUCTS						
1967	62.50	111.6	0.037	4.10	10.0	40.96
B-HI						
1980	128.25	229.0	0.037	8.41	10.0	84.05
1990	253.54	452.8	0.037	16.63	10.0	166.16
E-L0						
1980	110.51	197.4	0.037	7.25	10.0	72.42
1990	194.14	346.7	0.037	12.74	10.0	127.23
SELLER 74 - MISC PLSTC PRODS						
1967	378.49	660.1	0.021	14.06	12.5	175.68
B-HI						
1980	776.67	1354.5	0.021	28.85	12.5	360.50
1990	1535.41	2677.7	0.021	57.04	12.5	712.68
E-L0						
1980	669.21	1167.1	0.021	24.86	12.5	310.62
1990	1175.66	2050.3	0.021	43.67	12.5	545.69

	DOLLARS MILLIONS	WEIGHT MLN LBS	W/C	WASTE MLN LBS	H/C	HEAT BLN BTUS
TOTALS						
1967	1538.8	14971.4		793.8		7945.4
B-HI						
1980	3157.6	30721.6		1628.9		16304.1
1990	6242.4	60734.4		3220.2		32232.1
E-LO						
1980	2720.8	26471.2		1403.5		14048.5
1990	4779.8	46503.9		2465.7		24679.9

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BUYER     46 - OTHER FURNITURE                                                    PAGE 1

                    DOLLARS        WEIGHT       W/C         WASTE       H/C         HEAT
                    MILLIONS       MLN LBS                  MLN LBS                 BLN BTUS

SELLER    37 - MISC TEXTILES*

      1967            41.07         246.2     0.040            9.85     12.5        123.09

B-HI
      1980            54.63         327.5     0.040           13.10     12.5        163.72
      1990            81.86         490.7     0.040           19.63     12.5        245.35
E-LO
      1980            49.88         299.0     0.040           11.96     12.5        149.50
      1990            68.90         413.0     0.040           16.53     12.5        206.51

SELLER    41 - LMBR & WOOD PRODUCTS

      1967            65.80        1264.2     0.051           64.96     10.0        649.70

B-HI
      1980            87.52        1681.5     0.051           86.40     10.0        864.18
      1990           131.15        2519.8     0.051          129.48     10.0       1295.00
E-LO
      1980            79.92        1535.4     0.051           78.90     10.0        789.07
      1990           110.39        2120.9     0.051          108.98     10.0       1089.99

SELLER    42 - VENEER & PLYWOOD

      1967            67.20         852.7     0.024           20.40     10.0        203.91

B-HI
      1980            89.38        1134.2     0.024           27.13     10.0        271.23
      1990           133.94        1699.6     0.024           40.66     10.0        406.44
E-LO
      1980            81.62        1035.6     0.024           24.78     10.0        247.65
      1990           112.74        1430.6     0.024           34.22     10.0        342.10

SELLER    43 - MILLWORK & WOOD PROD

      1967            35.64         402.8     0.050           20.15     10.0        201.41

B-HI
      1980            47.41         535.8     0.050           26.80     10.0        267.90
      1990            71.04         803.0     0.050           40.16     10.0        401.46
E-LO
      1980            43.29         489.3     0.050           24.47     10.0        244.62
      1990            59.79         675.8     0.050           33.81     10.0        337.90

SELLER    68 - PAINTS

      1967            24.03          69.7     0.000            0.00      0.0          0.00

B-HI
      1980            31.96          92.7     0.000            0.00      0.0          0.00
      1990            47.90         138.9     0.000            0.00      0.0          0.00
E-LO
      1980            29.18          84.6     0.000            0.00      0.0          0.00
      1990            40.31         116.9     0.000            0.00      0.0          0.00
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BUYER     46 - OTHER FURNITURE                                          PAGE 2

                    DOLLARS      WEIGHT      W/C        WASTE      H/C       HEAT
                    MILLIONS     MLN LBS                MLN LBS              BLN BTUS

SELLER    74 - MISC PLSTC PRODS

     1967           134.28       207.0      0.003         0.53     12.4       6.59

B-HI
     1980           178.61       275.3      0.003         0.70     12.4       8.77
     1990           267.65       412.5      0.003         1.06     12.4      13.14
E-LO
     1980           163.09       251.4      0.003         0.64     12.4       8.00
     1990           225.28       347.2      0.003         0.89     12.4      11.06

SELLER    83 - STEEL

     1967           168.22      2065.4      0.000         0.00      0.0       0.00

B-HI
     1980           223.75      2747.2      0.000         0.00      0.0       0.00
     1990           335.30      4116.7      0.000         0.00      0.0       0.00
E-LO
     1980           204.31      2508.4      0.000         0.00      0.0       0.00
     1990           282.22      3465.0      0.000         0.00      0.0       0.00

TOTALS

     1967            536.2      5107.9                   115.9               1184.7

B-HI
     1980            713.3      6794.2                   154.1               1575.8
     1990           1068.8     10181.3                   231.0               2361.4
E-LO
     1980            651.3      6203.7                   140.8               1438.8
     1990            899.6      8569.5                   194.4               1987.6
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BUYER 47 - PULP MILLS

	DOLLARS MILLIONS	WEIGHT MLN LBS	W/C	WASTE MLN LBS	H/C	HEAT BLN BTUS
SELLER 32 - FATS & OILS						
1967	13.55	222.4	0.025	5.56	12.5	69.49
B-HI						
1980	23.60	387.2	0.025	9.68	12.5	121.02
1990	34.91	573.0	0.025	14.33	12.5	179.05
E-LO						
1980	21.98	360.7	0.025	9.02	12.5	112.74
1990	29.36	481.8	0.025	12.05	12.5	150.58
SELLER 41 - LMBR & WOOD PRODUCTS						
1967	185.05	34756.1	0.072	2518.5	7.5	18888.8
B-HI						
1980	322.27	60528.7	0.072	4387.2	7.5	32904.0
1990	476.82	89556.1	0.072	6490.2	7.5	48675.0
E-LO						
1980	300.21	56386.3	0.072	4085.0	7.5	30637.5
1990	400.99	75314.2	0.072	5457.6	7.5	40932.0
TOTALS						
1967	198.6	34978.5		2524.1		18958.3
B-HI						
1980	345.9	60916.0		4396.9		33025.0
1990	511.7	90129.0		6504.5		48854.0
E-LO						
1980	322.2	56747.0		4094.0		30750.4
1990	430.4	75796.0		5469.6		41082.6

BUYER 48 - PAPER & PPRBRD MILLS

	DOLLARS MILLIONS	WEIGHT MLN LBS	W/C	WASTE MLN LBS	H/C	HEAT BLN BTUS
SELLER 8 - FRSTRY & FSHRY PRODS						
1967	4.52	90.3	0.085	7.67	7.5	57.53
B-HI						
1980	7.76	155.1	0.042	6.58	7.5	49.45
1990	11.46	229.0	0.042	9.72	7.5	72.90
E-LO						
1980	7.19	143.7	0.021	6.10	7.5	45.75
1990	9.62	192.4	0.021	8.16	7.5	61.22
SELLER 9 - WHLSL TRADE WASTE*						
1967	270.82	17337.1	0.030	520.12	7.5	3900.83
B-HI						
1980	464.85	29758.0	0.030	892.75	7.5	6695.53
1990	686.51	43948.1	0.030	1318.47	7.5	9888.31
E-LO						
1980	430.76	27575.7	0.030	827.29	7.5	6204.53
1990	576.67	36917.0	0.030	1107.53	7.5	8306.29
SELLER 26 - GRAIN MILL PRODUCTS						
1967	72.06	1016.2	0.000	0.00	0.0	0.00
B-HI						
1980	123.69	1744.3	0.000	0.00	0.0	0.00
1990	182.67	2576.1	0.000	0.00	0.0	0.00
E-LO						
1980	114.62	1616.4	0.000	0.00	0.0	0.00
1990	153.44	2163.9	0.000	0.00	0.0	0.00
SELLER 32 - FATS & OILS						
1967	6.16	38.5	0.025	0.96	12.5	12.03
B-HI						
1980	10.57	66.1	0.025	1.65	12.5	20.65
1990	15.62	97.6	0.025	2.43	12.5	30.50
E-LO						
1980	9.80	61.2	0.025	1.53	12.5	19.13
1990	13.12	82.0	0.025	2.04	12.5	25.62
SELLER 41 - LMBR & WOOD PRODUCTS						
1967	985.79	179320.0	0.085	15242.2	7.5	114316.5
B-HI						
1980	1692.05	307791.8	0.042	13077.8	7.5	98083.5
1990	2498.90	454562.8	0.042	19319.5	7.5	144896.2
E-LO						
1980	1567.96	285220.4	0.021	12125.1	7.5	90938.6
1990	2099.11	381838.1	0.021	16225.3	7.5	121689.4

BUYER 48 - PAPER & PPRBRD MILLS

	DOLLARS MILLIONS	WEIGHT MLN LBS	W/C	WASTE MLN LBS	H/C	HEAT BLN BTUS
SELLER 47 - PULP MILLS						
1967	1595.00	27006.0	0.025	675.10	7.5	5063.20
B-HI						
1980	2737.72	46354.1	0.025	1158.77	7.5	8690.67
1990	4043.21	68458.2	0.025	1711.33	7.5	12834.83
E-LO						
1980	2536.95	42954.8	0.025	1073.79	7.5	8053.35
1990	3396.34	57505.7	0.025	1437.54	7.5	10781.41
SELLER 163 - WHOLESALE TRADE						
1967	34.97	448.5	0.000	0.00	0.0	0.00
B-HI						
1980	60.02	769.8	0.000	0.00	0.0	0.00
1990	88.65	1136.9	0.000	0.00	0.0	0.00
E-LO						
1980	55.62	713.4	0.000	0.00	0.0	0.00
1990	74.46	955.0	0.000	0.00	0.0	0.00
TOTALS						
1967	2969.3	225256.6		16446.05		123350.09
B-HI						
1980	5096.7	386639.0		14110.96		105836.23
1990	7527.0	571008.6		20845.33		156345.0
E-LO						
1980	4722.9	358285.5		130825.5		98122.90
1990	6322.8	479653.8		17507.00		131307.62

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BUYER     49 - PAPER PROD, NEC                                                   PAGE 1

                  DOLLARS       WEIGHT        W/C          WASTE        H/C         HEAT
                  MILLIONS      MLN LBS                    MLN LBS                  BLN BTUS

SELLER    47 - PULP MILLS

     1967           15.98         459.1      0.025          11.48        7.5          86.08

B-HI
     1980           27.12         779.2      0.025          19.48        7.5         146.09
     1990           38.64        1110.2      0.025          27.76        7.5         208.16
E-LO
     1980           25.58         735.0      0.025          18.38        7.5         137.81
     1990           33.34         958.0      0.025          23.95        7.5         179.62

SELLER    48 - PAPER & PPRBRD MILLS

     1967         1999.90       20249.8      0.020         405.00        7.5        3037.48

B-HI
     1980         3394.22       34367.9      0.020         687.36        7.5        5155.20
     1990         4836.21       48968.6      0.020         979.38        7.5        7345.31
E-LO
     1980         3201.73       32418.8      0.020         648.38        7.5        4862.83
     1990         4173.05       42253.9      0.020         845.09        7.5        6338.10

SELLER    61 - MISC CHEM PRODS

     1967           47.06         288.0      0.000           0.00        0.0           0.00

B-HI
     1980           79.87         488.8      0.000           0.00        0.0           0.00
     1990          113.80         696.4      0.000           0.00        0.0           0.00
E-LO
     1980           75.34         461.1      0.000           0.00        0.0           0.00
     1990           98.20         600.9      0.000           0.00        0.0           0.00

SELLER    62 - PLSTC MATRLS & RESNS

     1967          305.92        1867.8      0.022          41.09       12.5         513.63

B-HI
     1980          519.21        3169.9      0.022          69.74       12.5         871.73
     1990          739.78        4516.6      0.022          99.36       12.5        1242.07
E-LO
     1980          489.76        2990.2      0.022          65.78       12.5         822.29
     1990          638.34        3897.3      0.022          85.74       12.5        1071.76

SELLER    74 - MISC PLSTC PRODS

     1967          134.07         410.6      0.015           6.16       12.5          77.03

B-HI
     1980          227.54         696.9      0.015          10.45       12.5         130.74
     1990          324.21         993.0      0.015          14.90       12.5         186.28
E-LO
     1980          214.64         657.4      0.015           9.86       12.5         123.32
     1990          279.75         856.9      0.015          12.85       12.5         160.73
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	DOLLARS MILLIONS	WEIGHT MLN LBS	W/C	WASTE MLN LBS	H/C	HEAT BLN BTUS
TOTALS						
1967	2502.9	23275.3		463.7		3714.2
B-HI						
1980	4248.0	39502.7		787.0		6303.8
1990	6052.6	56284.9		1121.4		8981.8
E-LO						
1980	4007.0	37262.4		742.4		5946.3
1990	5222.7	48566.9		967.6		7750.2

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BUYER    50 - WALL & BLDG PAPER                                                  PAGE 1

               DOLLARS      WEIGHT      W/C        WASTE       H/C         HEAT
              MILLIONS     MLN LBS                MLN LBS                BLN BTUS

SELLER    9 - WHLSL TRADE WASTE*

    1967         13.77      1519.2    0.030        45.58       7.5       341.81

B-HI
    1980         23.10      2549.0    0.030        76.48       7.5       573.53
    1990         32.84      3623.1    0.030       108.70       7.5       815.19
E-L0
    1980         21.39      2359.3    0.030        70.79       7.5       530.84
    1990         28.18      3109.4    0.030        93.29       7.5       699.62

SELLER   41 - LMBR & W00D PR0DUCTS

    1967          2.31       278.6    0.085        23.68       7.5       177.6

B-HI
    1980          3.88       467.5    0.085        39.73       7.5       298.0
    1990          5.51       664.4    0.085        56.48       7.5       423.6
E-L0
    1980          3.59       432.7    0.085        36.78       7.5       275.9
    1990          4.73       570.2    0.085        48.47       7.5       363.5

SELLER   47 - PULP MILLS

    1967         18.78      1979.8    0.025        49.49       7.5       371.21

B-HI
    1980         31.51      3322.0    0.025        83.04       7.5       622.86
    1990         44.79      4721.7    0.025       118.03       7.5       885.30
E-L0
    1980         29.17      3074.7    0.025        76.86       7.5       576.50
    1990         38.44      4052.3    0.025       101.30       7.5       759.79

SELLER   48 - PAPER & PPRBRD MILLS

    1967          5.00        36.0    0.020         0.72       7.5         5.40

B-HI
    1980          8.39        60.4    0.020         1.21       7.5         9.06
    1990         11.92        85.9    0.020         1.72       7.5        12.88
E-L0
    1980          7.77        55.9    0.020         1.12       7.5         8.39
    1990         10.23        73.7    0.020         1.47       7.5        11.05

SELLER   74 - MISC PLSTC PR0DS

    1967          2.23         6.7    0.000         0.00       0.0         0.00

B-HI
    1980          3.74        11.2    0.000         0.00       0.0         0.00
    1990          5.32        16.0    0.000         0.00       0.0         0.00
E-L0
    1980          3.46        10.4    0.000         0.00       0.0         0.00
    1990          4.56        13.7    0.000         0.00       0.0         0.00
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BUYER 50 - WALL & BLDG PAPER

	DOLLARS MILLIONS	WEIGHT MLN LBS	W/C	WASTE MLN LBS	H/C	HEAT BLN BTUS
SELLER 163 - WHOLESALE TRADE						
1967	7.30	715.6	0.025	17.89	7.5	134.18
B-HI						
1980	12.25	1200.7	0.025	30.02	7.5	225.2
1990	17.41	1706.6	0.025	42.67	7.5	320.0
E-LO						
1980	11.34	1111.3	0.025	27.78	7.5	208.4
1990	14.94	1464.6	0.025	36.62	7.5	274.7
TOTALS						
1967	49.4	4535.8		137.36		1030.20
B-HI						
1980	82.9	7610.8		230.48		1728.65
1990	117.8	10817.6		327.60		2456.97
E-LO						
1980	76.7	7044.3		213.33		1600.03
1990	101.1	9284.0		281.15		2108.66

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BUYER    51 - PPRBOARD CONTAINERS                                        PAGE 1

                 DOLLARS      WEIGHT      W/C        WASTE      H/C        HEAT
                 MILLIONS     MLN LBS                MLN LBS               BLN BTUS

SELLER   48 - PAPER & PPRBRD MILLS

     1967        2534.72      36613.5    0.020       732.28     7.5      5492.02

B-HI
     1980        4120.69      59522.5    0.020      1190.47     7.5      8928.37
     1990        5796.77      83733.1    0.020      1674.68     7.5     12559.95
E-LO
     1980        3858.06      55728.9    0.020      1114.59     7.5      8359.32
     1990        4930.53      71220.5    0.020      1424.43     7.5     10683.06

SELLER   69 - PET RFNG & RLTD PRDS

     1967          22.00        277.0    0.030         8.31    12.5       103.88

B-HI
     1980          35.77        450.3    0.030        13.51    12.5       168.88
     1990          50.31        633.5    0.030        19.00    12.5       237.57
E-LO
     1980          33.49        421.6    0.030        12.65    12.5       158.11
     1990          42.79        538.8    0.030        16.16    12.5       202.07

TOTALS

     1967         2556.7      36890.5                 740.6                5595.9

B-HI
     1980         4156.5      59972.9                1204.0                9097.2
     1990         5847.1      84366.6                1693.7               12797.5
E-LO
     1980         3891.5      56150.5                1127.2                8517.4
     1990         4973.3      71759.3                1440.6               10885.1
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BUYER     52 - NEWSPAPER                                                    PAGE 1
                     DOLLARS      WEIGHT       W/C        WASTE       H/C       HEAT
                    MILLIONS     MLN LBS                 MLN LBS              BLN BTUS

SELLER    48 - PAPER & PPRBRD MILLS

     1967          1244.78      17713.5     0.008        141.70      7.5      1062.80

B-HI
     1980          2094.88      29810.6     0.008        238.47      7.5      1788.62
     1990          3135.29      44615.8     0.008        356.91      7.5      2676.93
E-LO
     1980          1927.83      27433.5     0.008        219.46      7.5      1645.99
     1990          2605.10      37071.1     0.008        296.55      7.5      2224.25

TOTALS

     1967           1244.8      17713.5                   141.7                1062.8

B-HI
     1980           2094.9      29810.6                   238.5                1788.6
     1990           3135.3      44615.8                   356.9                2676.9
E-LO
     1980           1927.8      27433.5                   219.5                1646.0
     1990           2605.1      37071.1                   296.6                2224.2
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BUYER     53 - BKS,PRDCLS,&MSC PUBS                                               PAGE 1

                    DOLLARS       WEIGHT      W/C          WASTE       H/C          HEAT
                    MILLIONS      MLN LBS                  MLN LBS                  BLN BTUS

SELLER    48 - PAPER & PPRBRD MILLS

    1967             735.56       5056.4     0.027         137.75      7.5        1033.04

B-HI
    1980            1337.73       9195.8     0.027         250.52      7.5        1878.75
    1990            2014.44      13847.6     0.027         377.25      7.5        2829.14
E-LO
    1980            1218.89       8378.9     0.027         228.26      7.5        1711.84
    1990            1616.02      11108.8     0.027         302.64      7.5        2269.59

SELLER    54 - OTR PRNTNG SERVICES

    1967             114.21          0.0     0.000           0.00      0.0           0.00

B-HI
    1980             207.71          0.0     0.000           0.00      0.0           0.00
    1990             312.78          0.0     0.000           0.00      0.0           0.00
E-LO
    1980             189.26          0.0     0.000           0.00      0.0           0.00
    1990             250.92          0.0     0.000           0.00      0.0           0.00

SELLER   145 - PHOTO EQUIPMENT

    1967              39.44        106.6     0.000           0.00      0.0           0.00

B-HI
    1980              71.73        193.8     0.000           0.00      0.0           0.00
    1990             108.01        291.9     0.000           0.00      0.0           0.00
E-LO
    1980              65.36        176.6     0.000           0.00      0.0           0.00
    1990              86.65        234.2     0.000           0.00      0.0           0.00

SELLER   149 - OFFICE SUPPLIES

    1967              41.85        274.6     0.000           0.00      0.0           0.00

B-HI
    1980              76.11        499.5     0.000           0.00      0.0           0.00
    1990             114.61        752.1     0.000           0.00      0.0           0.00
E-LO
    1980              69.35        455.1     0.000           0.00      0.0           0.00
    1990              91.94        603.4     0.000           0.00      0.0           0.00

TOTALS

    1967              931.1       5437.6                    137.8                  1033.0

B-HI
    1980             1693.3       9889.1                    250.5                  1878.7
    1990             2549.9      14891.7                    377.2                  2829.1
E-LO
    1980             1542.8       9010.6                    228.3                  1711.8
    1990             2045.5      11946.4                    302.6                  2269.6
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BUYER     54 - OTR PRNTNG SERVICES                                      PAGE 1

                    DOLLARS      WEIGHT      W/C        WASTE      H/C        HEAT
                   MILLIONS     MLN LBS                MLN LBS              BLN BTUS

SELLER    43 - MILLWORK & WOOD PROD

     1967            33.03         66.0    0.050          3.30    10.0        33.03

B-HI
     1980            61.19        122.4    0.050          6.11    10.0        61.19
     1990            99.10        198.2    0.050          9.90    10.0        99.10
E-LO
     1980            55.28        110.5    0.050          5.52    10.0        55.28
     1990            81.46        162.9    0.050          8.14    10.0        81.46

SELLER    48 - PAPER & PPRBRD MILLS

     1967          1615.02      14383.5    0.037        525.41     7.5      3940.48

B-HI
     1980          2992.07      26647.6    0.037        973.40     7.5      7300.33
     1990          4845.45      43154.0    0.037       1576.36     7.5     11822.39
E-LO
     1980          2702.87      24072.0    0.037        879.32     7.5      6594.72
     1990          3983.13      35474.1    0.037       1295.82     7.5      9718.42

TOTALS

     1967           1648.0      14449.5                  528.7               3973.5

B-HI
     1980           3053.3      26770.0                  979.5               7361.5
     1990           4944.5      43352.1                 1586.3              11921.5
E-LO
     1980           2758.1      24182.5                  884.8               6650.0
     1990           4064.6      35637.0                 1304.0               9799.9
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BUYER     55 - INDUSTRIAL CHEMICALS                                         PAGE 1

                  DOLLARS      WEIGHT      W/C          WASTE      H/C        HEAT
                  MILLIONS     MLN LBS                  MLN LBS              BLN BTUS

SELLER    49 - PAPER PROD, NEC

    1967           81.00        326.0    0.000            0.00     0.0        0.00

B-HI
    1980          135.01        543.4    0.000            0.00     0.0        0.00
    1990          189.34        762.0    0.000            0.00     0.0        0.00
E-LO
    1980          126.70        509.9    0.000            0.00     0.0        0.00
    1990          162.23        652.9    0.000            0.00     0.0        0.00

SELLER    83 - STEEL

    1967           27.80       2800.7    0.000            0.00     0.0        0.00

B-HI
    1980           46.34       4668.2    0.000            0.00     0.0        0.00
    1990           64.98       6546.9    0.000            0.00     0.0        0.00
E-LO
    1980           43.48       4380.8    0.000            0.00     0.0        0.00
    1990           55.68       5609.4    0.000            0.00     0.0        0.00

TOTALS

    1967           108.8       3126.7                      0.0                 0.0

B-HI
    1980           181.3       5211.5                      0.0                 0.0
    1990           254.3       7309.0                      0.0                 0.0
E-LO
    1980           170.2       4890.7                      0.0                 0.0
    1990           217.9       6262.4                      0.0                 0.0
```

BUYER 62 - PLSTC MATRLS & RESNS

	DOLLARS MILLIONS	WEIGHT MLN LBS	W/C	WASTE MLN LBS	H/C	HEAT BLN BTUS
SELLER 47 - PULP MILLS						
1967	36.20	560.6	0.025	14.01	7.5	105.11
B-HI						
1980	73.58	1139.4	0.025	28.48	7.5	213.64
1990	127.43	1973.4	0.025	49.32	7.5	370.00
E-LO						
1980	67.95	1052.3	0.025	26.30	7.5	197.31
1990	106.49	1649.1	0.025	41.21	7.5	309.20
TOTALS						
1967	36.2	560.6		14.0		105.1
B-HI						
1980	73.6	1139.4		28.5		213.6
1990	127.4	1973.4		49.3		370.0
E-LO						
1980	68.0	1052.3		26.3		197.3
1990	106.5	1649.1		41.2		309.2

BUYER 63 - SYNTHETIC RUBBER

	DOLLARS MILLIONS	WEIGHT MLN LBS	W/C	WASTE MLN LBS	H/C	HEAT BLN BTUS
SELLER 61 - MISC CHEM PRODS						
1967	29.30	393.1	0.000	0.00	0.0	0.00
B-HI						
1980	43.11	578.3	0.000	0.00	0.0	0.00
1990	58.49	784.7	0.000	0.00	0.0	0.00
E-LO						
1980	40.03	537.0	0.000	0.00	0.0	0.00
1990	49.62	665.7	0.000	0.00	0.0	0.00
TOTALS						
1967	29.3	393.1		0.0		0.0
B-HI						
1980	43.1	578.3		0.0		0.0
1990	58.5	784.7		0.0		0.0
E-LO						
1980	40.0	537.0		0.0		0.0
1990	49.6	665.7		0.0		0.0

BUYER 64 - CELLULOSIC FIBERS

	DOLLARS MILLIONS	WEIGHT MLN LBS	W/C	WASTE MLN LBS	H/C	HEAT BLN BTUS
SELLER 47 - PULP MILLS						
1967	139.18	1469.8	0.025	36.75	7.5	275.59
B-HI						
1980	255.43	2697.5	0.025	67.45	7.5	505.78
1990	366.38	3869.1	0.025	96.74	7.5	725.46
E-LO						
1980	245.09	2588.2	0.025	64.71	7.5	485.30
1990	309.10	3264.3	0.025	81.62	7.5	612.05
TOTALS						
1967	139.2	1469.8		36.8		275.6
B-HI						
1980	255.4	2697.5		67.4		505.8
1990	366.4	3869.1		96.7		725.5
E-LO						
1980	245.1	2588.2		64.7		485.3
1990	309.1	3264.3		81.6		612.1

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BUYER    66 - DRUGS

                   DOLLARS      WEIGHT       W/C         WASTE      H/C        HEAT
                  MILLIONS     MLN LBS                  MLN LBS              BLN BTUS

SELLER   28 - SUGAR

    1967             59.20        59.6    0.000          0.00      0.0         0.00

B-HI
    1980             90.82        91.4    0.000          0.00      0.0         0.00
    1990            156.82       157.9    0.000          0.00      0.0         0.00
E-LO
    1980             91.32        91.9    0.000          0.00      0.0         0.00
    1990            146.45       147.4    0.000          0.00      0.0         0.00

SELLER   74 - MISC PLSTC PRODS

    1967            129.07       291.1    0.000          0.00      0.0         0.00

B-HI
    1980            198.01       446.6    0.000          0.00      0.0         0.00
    1990            341.91       771.2    0.000          0.00      0.0         0.00
E-LO
    1980            199.09       449.1    0.000          0.00      0.0         0.00
    1990            319.29       720.2    0.000          0.00      0.0         0.00

TOTALS

    1967             188.3       350.7                    0.0                   0.0

B-HI
    1980             288.8       538.1                    0.0                   0.0
    1990             498.7       929.1                    0.0                   0.0
E-LO
    1980             290.4       541.0                    0.0                   0.0
    1990             465.7       867.6                    0.0                   0.0
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BUYER    67 - CLNNG & TOILET PREPS                                          PAGE 1

                    DOLLARS      WEIGHT      W/C        WASTE     H/C       HEAT
                   MILLIONS     MLN LBS               MLN LBS             BLN BTUS

SELLER   32 - FATS & OILS

     1967          190.82        986.3     0.000        0.00      0.0       0.00

B-HI
     1980          318.72       1647.3     0.000        0.00      0.0       0.00
     1990          378.28       1955.1     0.000        0.00      0.0       0.00
E-LO
     1980          309.23       1598.3     0.000        0.00      0.0       0.00
     1990          335.30       1733.0     0.000        0.00      0.0       0.00

SELLER   49 - PAPER PROD, NEC

     1967           55.00        224.0     0.000        0.00      0.0       0.00

B-HI
     1980           91.86        374.1     0.000        0.00      0.0       0.00
     1990          109.03        444.1     0.000        0.00      0.0       0.00
E-LO
     1980           89.13        363.0     0.000        0.00      0.0       0.00
     1990           96.64        393.6     0.000        0.00      0.0       0.00

SELLER   74 - MISC PLSTC PRODS

     1967          113.27        306.1     0.008        2.47     12.5      30.82

B-HI
     1980          189.19        511.3     0.008        4.13     12.5      51.48
     1990          224.55        606.9     0.008        4.90     12.5      61.10
E-LO
     1980          183.56        496.1     0.008        4.00     12.5      49.94
     1990          199.03        537.9     0.008        4.34     12.5      54.15

TOTALS

     1967           359.1       1516.4                   2.5                30.8

B-HI
     1980           599.8       2532.8                   4.1                51.5
     1990           711.9       3006.1                   4.9                61.1
E-LO
     1980           581.9       2457.4                   4.0                49.9
     1990           631.0       2664.5                   4.3                54.2
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BUYER 68 - PAINTS

	DOLLARS MILLIONS	WEIGHT MLN LBS	W/C	WASTE MLN LBS	H/C	HEAT BLN BTUS
SELLER 32 - FATS & OILS						
1967	99.07	407.6	0.000	0.00	0.0	0.00
B-HI						
1980	163.67	673.3	0.000	0.00	0.0	0.00
1990	237.36	976.4	0.000	0.00	0.0	0.00
E-LO						
1980	151.61	623.7	0.000	0.00	0.0	0.00
1990	200.33	824.1	0.000	0.00	0.0	0.00
SELLER 62 - PLSTC MATRLS & RESNS						
1967	280.44	845.0	0.022	18.59	12.5	232.38
B-HI						
1980	463.32	1396.0	0.022	30.71	12.5	383.92
1990	671.89	2024.5	0.022	44.54	12.5	556.74
E-LO						
1980	429.16	1293.1	0.022	28.45	12.5	355.61
1990	567.09	1708.7	0.022	37.59	12.5	469.91
TOTALS						
1967	379.5	1252.6		18.6		232.4
B-HI						
1980	627.0	2069.4		30.7		383.9
1990	909.2	3000.9		44.5		556.7
E-LO						
1980	580.8	1916.8		28.4		355.6
1990	767.4	2532.9		37.6		469.9

BUYER 71 - PAVING & ASPHALT

PAGE 1

	DOLLARS MILLIONS	WEIGHT MLN LBS	W/C	WASTE MLN LBS	H/C	HEAT BLN BTUS
SELLER 50 - WALL & BLDG PAPER						
1967	86.36	3233.2	0.002	6.46	7.5	48.5
B-HI						
1980	155.68	5828.4	0.002	11.65	7.5	87.4
1990	215.93	8084.0	0.002	16.16	7.5	121.3
E-L0						
1980	140.95	5276.9	0.002	10.55	7.5	79.2
1990	179.62	6724.8	0.002	13.44	7.5	100.9
SELLER 69 - PET RFNG & RLTD PRDS						
1967	202.25	18903.2	0.000	0.000	12.5	0.0
B-HI						
1980	364.59	34076.6	0.000	0.000	12.5	0.0
1990	505.69	47263.9	0.000	0.000	12.5	0.0
E-L0						
1980	330.10	30852.3	0.000	0.000	12.5	0.0
1990	420.67	39317.5	0.000	0.000	12.5	0.0
TOTALS						
1967	288.6	22136.4		6.46		48.5
B-HI						
1980	520.3	39905.1		11.65		87.4
1990	721.6	55347.5		16.16		121.3
E-L0						
1980	471.0	36129.2		10.55		79.2
1990	600.3	46042.4		13.44		100.9

BUYER 72 - TIRES & INNER TUBES

	DOLLARS MILLIONS	WEIGHT MLN LBS	W/C	WASTE MLN LBS	H/C	HEAT BLN BTUS
SELLER 40 - HOUSEHOLD TEXTILES*						
1967	404.60	478.9	0.040	19.16	12.5	239.45
B-HI						
1980	590.37	698.8	0.040	27.96	12.5	349.39
1990	747.77	885.1	0.040	35.41	12.5	442.55
E-LO						
1980	554.53	656.4	0.040	26.26	12.5	328.16
1990	643.98	762.2	0.040	30.50	12.5	381.12
SELLER 63 - SYNTHETIC RUBBER						
1967	420.00	2221.0	0.032	71.86	12.5	898.20
B-HI						
1980	612.84	3240.4	0.032	104.85	12.5	1310.60
1990	776.23	4104.4	0.032	132.81	12.5	1660.03
E-LO						
1980	575.64	3045.0	0.032	98.49	12.5	1231.05
1990	668.50	3535.8	0.032	114.38	12.5	1429.62
TOTALS						
1967	824.6	2699.9		91.0		1137.6
B-HI						
1980	1203.2	3939.2		132.8		1660.0
1990	1524.0	4989.5		168.2		2102.6
E-LO						
1980	1130.2	3701.4		124.7		1559.2
1990	1312.5	4298.0		144.9		1810.7

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BUYER    73 - RUBBER PRODUCTS                                                PAGE 1

                  DOLLARS       WEIGHT      W/C         WASTE      H/C         HEAT
                  MILLIONS     MLN LBS                 MLN LBS              BLN BTUS

SELLER   35 - BROAD & NARROW FBRCS

    1967          105.20         77.8     0.040           3.11     10.0        31.10

B-HI
    1980          164.39        121.5     0.040           4.86     10.0        48.60
    1990          256.43        189.5     0.040           7.58     10.0        75.81
E-LO
    1980          148.80        110.0     0.040           4.40     10.0        43.99
    1990          211.73        156.5     0.040           6.26     10.0        62.59

SELLER   55 - INDUSTRIAL CHEMICALS

    1967          105.00        637.0     0.006           3.72     12.5        46.47

B-HI
    1980          164.08        995.4     0.006           5.81     12.5        72.62
    1990          255.95       1552.7     0.006           9.07     12.5       113.28
E-LO
    1980          148.52        901.0     0.006           5.26     12.5        65.73
    1990          211.33       1282.1     0.006           7.49     12.5        93.53

SELLER   61 - MISC CHEM PRODS

    1967           25.00        312.0     0.000           0.00      0.0         0.00

B-HI
    1980           39.07        487.5     0.000           0.00      0.0         0.00
    1990           60.94        760.5     0.000           0.00      0.0         0.00
E-LO
    1980           35.36        441.3     0.000           0.00      0.0         0.00
    1990           50.32        628.0     0.000           0.00      0.0         0.00

SELLER   62 - PLSTC MATRLS & RESNS

    1967           35.00        178.0     0.022           3.92     12.5        48.95

B-HI
    1980           54.69        278.1     0.022           6.13     12.5        76.49
    1990           85.32        433.9     0.022           9.56     12.5       119.32
E-LO
    1980           49.51        251.8     0.022           5.54     12.5        69.24
    1990           70.44        358.3     0.022           7.89     12.5        98.52

SELLER   63 - SYNTHETIC RUBBER

    1967          258.00       1017.6     0.072          73.28     12.5       915.84

B-HI
    1980          403.16       1590.1     0.072         114.51     12.5      1431.11
    1990          628.90       2480.5     0.072         178.63     12.5      2232.45
E-LO
    1980          364.94       1439.4     0.072         103.65     12.5      1295.44
    1990          519.27       2048.1     0.072         147.49     12.5      1843.29
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BUYER 73 - RUBBER PRODUCTS

	DOLLARS MILLIONS	WEIGHT MLN LBS	W/C	WASTE MLN LBS	H/C	HEAT BLN BTUS
TOTALS						
1967	528.2	2222.3		84.0		1042.4
B-HI						
1980	825.4	3472.7		131.3		1628.8
1990	1287.5	5417.2		204.8		2540.9
E-LO						
1980	747.1	3143.5		118.9		1474.4
1990	1063.1	4472.9		169.1		2097.9

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BUYER     74 - MISC PLSTC PRØDS
                                                                              PAGE 1
                  DØLLARS       WEIGHT       W/C        WASTE       H/C       HEAT
                  MILLIØNS      MLN LBS                 MLN LBS               BLN BTUS

SELLER    35 - BRØAD & NARRØW FBRCS

     1967          22.88          43.7      0.040        1.75      10.0       17.49

B-HI
     1980          50.74          97.0      0.040        3.88      10.0       38.79
     1990          80.25         153.4      0.040        6.14      10.0       61.35
E-LØ
     1980          46.33          88.5      0.040        3.54      10.0       35.41
     1990          65.62         125.4      0.040        5.02      10.0       50.16

SELLER    55 - INDUSTRIAL CHEMICALS

     1967          34.56         170.4      0.022        3.75      12.5       46.87

B-HI
     1980          76.65         378.0      0.022        8.32      12.5      103.95
     1990         121.22         597.8      0.022       13.15      12.5      164.40
E-LØ
     1980          69.97         345.1      0.022        7.59      12.5       94.90
     1990          99.12         488.8      0.022       10.76      12.5      134.43

SELLER    62 - PLSTC MATRLS & RESNS

     1967        1268.14        5589.8      0.022      122.98      12.5     1537.20

B-HI
     1980        2812.52       12397.3      0.022      272.75      12.5     3409.25
     1990        4448.07       19606.6      0.022      431.36      12.5     5391.81
E-LØ
     1980        2567.64       11317.9      0.022      249.00      12.5     3112.41
     1990        3637.23       16032.5      0.022      352.73      12.5     4408.93

SELLER    74 - MISC PLSTC PRØDS

     1967          87.01         216.9      0.000        0.00       0.0        0.00

B-HI
     1980         192.97         481.1      0.000        0.00       0.0        0.00
     1990         305.19         760.9      0.000        0.00       0.0        0.00
E-LØ
     1980         176.17         439.2      0.000        0.00       0.0        0.00
     1990         249.56         622.2      0.000        0.00       0.0        0.00

TØTALS

     1967         1412.6        6020.9                  128.5                 1601.6

B-HI
     1980         3132.9       13353.4                  284.9                 3552.0
     1990         4954.7       21118.7                  450.7                 5617.6
E-LØ
     1980         2860.1       12190.7                  260.1                 3242.7
     1990         4051.5       17268.9                  368.5                 4593.5
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BUYER    75 - LTHR TAN & INDS LTHR                                      PAGE 1

                  DOLLARS      WEIGHT      W/C        WASTE       H/C        HEAT
                 MILLIONS     MLN LBS                MLN LBS               BLN BTUS

SELLER   23 - MEAT PRODUCTS

    1967          320.85       324.7     0.250        81.17     10.0      811.70

B-HI
    1980          476.29       482.0     0.250       120.49     10.0     1204.95
    1990          867.21       877.6     0.250       219.39     10.0     2193.92
E-LO
    1980          304.85       308.5     0.250        77.12     10.0      771.22
    1990          528.70       535.0     0.250       133.75     10.0     1337.54

SELLER   42 - VENEER & PLYWOOD

    1967            0.00        23.0     0.050         1.15     10.0       11.50

B-HI
    1980            0.00        34.1     0.050         1.71     10.0       17.07
    1990            0.00        62.2     0.050         3.11     10.0       31.08
E-LO
    1980            0.00        21.9     0.050         1.09     10.0       10.93
    1990            0.00        37.9     0.050         1.89     10.0       18.95

SELLER   75 - LTHR TAN & INDS LTHR

    1967           22.31        31.9     0.000         0.00      0.0        0.00

B-HI
    1980           33.12        47.3     0.000         0.00      0.0        0.00
    1990           60.30        86.1     0.000         0.00      0.0        0.00
E-LO
    1980           21.20        30.3     0.000         0.00      0.0        0.00
    1990           36.76        52.5     0.000         0.00      0.0        0.00

TOTALS

    1967           343.2       379.5                   82.3                 823.2

B-HI
    1980           509.4       563.4                  122.2                1222.0
    1990           927.5      1025.9                  222.5                2225.0
E-LO
    1980           326.0       360.6                   78.2                 782.2
    1990           565.5       625.4                  135.6                1356.5
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BUYER 76 - LEATHER FOOTWEAR

	DOLLARS MILLIONS	WEIGHT MLN LBS	W/C	WASTE MLN LBS	H/C	HEAT BLN BTUS
SELLER 35 - BROAD & NARROW FBRCS						
1967	42.45	29.2	0.040	1.17	7.5	8.76
B-HI						
1980	60.63	41.7	0.040	1.67	7.5	12.51
1990	117.17	80.6	0.040	3.23	7.5	24.18
E-LO						
1980	33.65	23.1	0.040	0.93	7.5	6.94
1990	65.31	44.9	0.040	1.80	7.5	13.48
SELLER 37 - MISC TEXTILES*						
1967	31.40	188.0	0.040	7.52	12.5	94.00
B-HI						
1980	44.85	268.5	0.040	10.74	12.5	134.26
1990	86.67	518.9	0.040	20.76	12.5	259.47
E-LO						
1980	24.89	149.0	0.040	5.96	12.5	74.51
1990	48.31	289.2	0.040	11.57	12.5	144.62
SELLER 42 - VENEER & PLYWOOD						
1967	7.84	1.3	0.053	0.07	9.3	0.65
B-HI						
1980	11.20	1.9	0.053	0.10	9.3	0.93
1990	21.64	3.6	0.053	0.19	9.3	1.79
E-LO						
1980	6.21	1.0	0.053	0.06	9.3	0.52
1990	12.06	2.0	0.053	0.11	9.3	1.00
SELLER 43 - MILLWORK & WOOD PROD						
1967	45.72	91.4	0.000	0.00	0.0	0.00
B-HI						
1980	65.30	130.6	0.000	0.00	0.0	0.00
1990	126.20	252.4	0.000	0.00	0.0	0.00
E-LO						
1980	36.24	72.5	0.000	0.00	0.0	0.00
1990	70.34	140.7	0.000	0.00	0.0	0.00
SELLER 73 - RUBBER PRODUCTS						
1967	204.23	204.2	0.045	9.17	10.0	91.75
B-HI						
1980	291.70	291.7	0.045	13.10	10.0	131.04
1990	563.73	563.7	0.045	25.31	10.0	253.26
E-LO						
1980	161.89	161.9	0.045	7.27	10.0	72.73
1990	314.21	314.2	0.045	14.11	10.0	141.16

BUYER 76 - LEATHER FOOTWEAR

	DOLLARS MILLIONS	WEIGHT MLN LBS	W/C	WASTE MLN LBS	H/C	HEAT BLN BTUS
SELLER 74 - MISC PLSTC PRODS						
1967	35.89	48.4	0.022	1.06	12.6	13.31
B-HI						
1980	51.26	69.1	0.022	1.51	12.6	19.01
1990	99.07	133.6	0.022	2.93	12.6	36.74
E-L0						
1980	28.45	38.4	0.022	0.84	12.6	10.55
1990	55.22	74.4	0.022	1.63	12.6	20.48
SELLER 75 - LTHR TAN & INDS LTHR						
1967	722.58	660.4	0.000	0.00	0.0	0.00
B-HI						
1980	1032.04	943.3	0.000	0.00	0.0	0.00
1990	1994.52	1823.0	0.000	0.00	0.0	0.00
E-L0						
1980	572.79	523.5	0.000	0.00	0.0	0.00
1990	1111.70	1016.1	0.000	0.00	0.0	0.00
TOTALS						
1967	1090.1	1223.0		19.0		208.5
B-HI						
1980	1557.0	1746.8		27.1		297.8
1990	3009.0	3375.8		52.4		575.4
E-L0						
1980	864.1	969.5		15.1		165.3
1990	1677.1	1881.6		29.2		320.7

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BUYER    77 - 0TR LEATHER PR0DUCTS                                              PAGE 1

                  D0LLARS       WEIGHT       W/C         WASTE      H/C        HEAT
                  MILLI0NS      MLN LBS                  MLN LBS              BLN BTUS

SELLER    37 - MISC TEXTILES*

     1967          125.13        202.1      0.040         8.09      11.7        94.42

B-HI
     1980          211.33        341.3      0.040        13.66      11.7       159.46
     1990          308.74        498.7      0.040        19.96      11.7       232.96
E-L0
     1980          194.74        314.5      0.040        12.59      11.7       146.95
     1990          263.16        425.0      0.040        17.01      11.7       198.57

SELLER    40 - H0USEH0LD TEXTILES*

     1967           34.20        205.0      0.040         8.20      10.0        82.00

B-HI
     1980           57.76        346.2      0.040        13.85      10.0       138.49
     1990           84.38        505.8      0.040        20.23      10.0       202.32
E-L0
     1980           53.23        319.0      0.040        12.76      10.0       127.62
     1990           71.92        431.1      0.040        17.25      10.0       172.45

SELLER    74 - MISC PLSTC PR0DS

     1967           26.29          5.0      0.022         0.11      12.5         1.37

B-HI
     1980           44.40          8.4      0.022         0.19      12.5         2.31
     1990           64.87         12.3      0.022         0.27      12.5         3.38
E-L0
     1980           40.92          7.7      0.022         0.17      12.5         2.13
     1990           55.29         10.5      0.022         0.23      12.5         2.88

SELLER    75 - LTHR TAN & INDS LTHR

     1967          116.12         30.7      0.000         0.00       0.0         0.00

B-HI
     1980          196.11         51.9      0.000         0.00       0.0         0.00
     1990          286.51         75.8      0.000         0.00       0.0         0.00
E-L0
     1980          180.72         47.8      0.000         0.00       0.0         0.00
     1990          244.21         64.6      0.000         0.00       0.0         0.00

T0TALS

     1967          301.7         442.8                   16.4                  177.8

B-HI
     1980          509.6         747.8                   27.7                  300.3
     1990          744.5        1092.5                   40.5                  438.7
E-L0
     1980          469.6         689.1                   25.5                  276.7
     1990          634.6         931.2                   34.5                  373.9
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BUYER 78 - GLASS

	DOLLARS MILLIONS	WEIGHT MLN LBS	W/C	WASTE MLN LBS	H/C	HEAT BLN BTUS
SELLER 43 - MILLWORK & WOOD PROD						
1967	34.00	68.0	0.000	0.00	0.0	0.00
B-HI						
1980	55.71	111.4	0.000	0.00	0.0	0.00
1990	92.40	184.8	0.000	0.00	0.0	0.00
E-LO						
1980	50.88	101.8	0.000	0.00	0.0	0.00
1990	75.82	151.6	0.000	0.00	0.0	0.00
SELLER 74 - MISC PLSTC PRODS						
1967	79.00	160.0	0.000	0.00	0.0	0.00
B-HI						
1980	129.44	262.2	0.000	0.00	0.0	0.00
1990	214.70	434.8	0.000	0.00	0.0	0.00
E-LO						
1980	118.23	239.5	0.000	0.00	0.0	0.00
1990	176.17	356.8	0.000	0.00	0.0	0.00
TOTALS						
1967	113.0	228.0		0.0		0.0
B-HI						
1980	185.2	373.6		0.0		0.0
1990	307.1	619.6		0.0		0.0
E-LO						
1980	169.1	341.2		0.0		0.0
1990	252.0	508.4		0.0		0.0

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BUYER     81 - CMNT,CNCRT, & GYPSUM                                            PAGE 1

                  DOLLARS       WEIGHT       W/C        WASTE       H/C        HEAT
                 MILLIONS      MLN LBS                 MLN LBS               BLN BTUS

SELLER    48 - PAPER & PPRBRD MILLS

     1967         45.00        1100.0      0.040        44.00       7.5       330.00

B-HI
     1980         73.26        1790.8      0.040        71.63       7.5       537.23
     1990         99.01        2420.3      0.040        96.81       7.5       726.10
E-LO
     1980         64.15        1568.2      0.040        62.73       7.5       470.45
     1990         79.84        1951.7      0.040        78.07       7.5       585.51

SELLER    49 - PAPER PROD, NEC

     1967         27.00         650.6      0.000         0.00       0.0         0.00

B-HI
     1980         43.95        1059.2      0.000         0.00       0.0         0.00
     1990         59.41        1431.6      0.000         0.00       0.0         0.00
E-LO
     1980         38.49         927.5      0.000         0.00       0.0         0.00
     1990         47.91        1154.4      0.000         0.00       0.0         0.00

TOTALS

     1967          72.0        1750.6                    44.0                  330.0

B-HI
     1980         117.2        2850.0                    71.6                  537.2
     1990         158.4        3851.9                    96.8                  726.1
E-LO
     1980         102.6        2495.7                    62.7                  470.4
     1990         127.7        3106.1                    78.1                  585.5
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ANDERSON JACOBSON, INC.

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BUYER    82 - OTR STONE&CLAY PRODS                                      PAGE 1

                  DOLLARS     WEIGHT     W/C         WASTE      H/C       HEAT
                 MILLIONS    MLN LBS                MLN LBS              BLN BTUS

SELLER   62 - PLSTC MATRLS & RESNS

     1967          71.00       567.0    0.022         12.47     12.5      155.93

B-HI
     1980         111.42       889.8    0.022         19.57     12.5      244.70
     1990         153.74      1227.8    0.022         27.00     12.5      337.65
E-LO
     1980         102.64       819.7    0.022         18.03     12.5      225.42
     1990         130.29      1040.5    0.022         22.88     12.5      286.14

TOTALS

     1967          71.0        567.0                   12.5                155.9

B-HI
     1980         111.4        889.8                   19.6                244.7
     1990         153.7       1227.8                   27.0                337.6
E-LO
     1980         102.6        819.7                   18.0                225.4
     1990         130.3       1040.5                   22.9                286.1
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ANDERSON JACOBSON, INC.

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BUYER     90 - NONIRN WR DRNG&INSUL                                              PAGE 1

                   DOLLARS       WEIGHT       W/C           WASTE       H/C          HEAT
                  MILLIONS      MLN LBS                    MLN LBS                 BLN BTUS

SELLER    43 - MILLWORK & WOOD PROD

     1967           35.00          69.0     0.000            0.00       0.0          0.00

B-HI
     1980           50.50          99.6     0.000            0.00       0.0          0.00
     1990           68.61         135.3     0.000            0.00       0.0          0.00
E-LO
     1980           46.58          91.8     0.000            0.00       0.0          0.00
     1990           57.46         113.3     0.000            0.00       0.0          0.00

SELLER    63 - SYNTHETIC RUBBER

     1967           29.00          98.0     0.072            7.06      12.5         88.20

B-HI
     1980           41.84         141.4     0.072           10.19      12.5        127.25
     1990           56.85         192.1     0.072           13.84      12.5        172.91
E-LO
     1980           38.59         130.4     0.072            9.40      12.5        117.38
     1990           47.61         160.9     0.072           11.59      12.5        144.80

TOTALS

     1967            64.0         167.0                       7.1                    88.2

B-HI
     1980            92.3         240.9                      10.2                   127.3
     1990           125.5         327.4                      13.8                   172.9
E-LO
     1980            85.2         222.3                       9.4                   117.4
     1990           105.1         274.2                      11.6                   144.8
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BUYER 92 - METAL CANS

	DOLLARS MILLIONS	WEIGHT MLN LBS	W/C	WASTE MLN LBS	H/C	HEAT BLN BTUS
SELLER 68 - PAINTS						
1967	55.62	175.9	0.000	0.00	0.0	0.00
B-HI						
1980	85.72	271.0	0.000	0.00	0.0	0.00
1990	102.20	323.1	0.000	0.00	0.0	0.00
E-LO						
1980	82.98	262.4	0.000	0.00	0.0	0.00
1990	93.25	294.9	0.000	0.00	0.0	0.00
TOTALS						
1967	55.6	175.9		0.0		0.0
B-HI						
1980	85.7	271.0		0.0		0.0
1990	102.2	323.1		0.0		0.0
E-LO						
1980	83.0	262.4		0.0		0.0
1990	93.3	294.9		0.0		0.0

ANDERSON JACOBSON, INC.

BUYER 97 - METAL STAMPINGS

	DOLLARS MILLIONS	WEIGHT MLN LBS	W/C	WASTE MLN LBS	H/C	HEAT BLN BTUS
SELLER 43 - MILLWORK & WOOD PROD						
1967	45.05	91.2	0.000	0.00	0.0	0.00
B-HI						
1980	75.32	152.5	0.000	0.00	0.0	0.00
1990	112.92	228.6	0.000	0.00	0.0	0.00
E-LO						
1980	66.16	133.9	0.000	0.00	0.0	0.00
1990	88.02	178.2	0.000	0.00	0.0	0.00
SELLER 62 - PLSTC MATRLS & RESNS						
1967	15.38	60.4	0.022	1.33	12.5	16.62
B-HI						
1980	25.71	101.0	0.022	2.22	12.5	27.79
1990	38.55	151.5	0.022	3.33	12.5	41.66
E-LO						
1980	22.59	88.7	0.022	1.95	12.5	24.41
1990	30.05	118.1	0.022	2.60	12.5	32.47
TOTALS						
1967	60.4	151.6		1.3		16.6
B-HI						
1980	101.0	253.5		2.2		27.8
1990	151.5	380.1		3.3		41.7
E-LO						
1980	88.7	222.7		2.0		24.4
1990	118.1	296.3		2.6		32.5

BUYER 98 - CUTLRY, HAND TOOLS

SELLER 43 - MILLWORK & WOOD PROD

	DOLLARS MILLIONS	WEIGHT MLN LBS	W/C	WASTE MLN LBS	H/C	HEAT BLN BTUS
1967	49.00	98.0	0.000	0.00	0.0	0.00
B-HI						
1980	85.19	170.4	0.000	0.00	0.0	0.00
1990	134.41	268.8	0.000	0.00	0.0	0.00
E-LO						
1980	72.53	145.1	0.000	0.00	0.0	0.00
1990	99.62	199.2	0.000	0.00	0.0	0.00

TOTALS

	DOLLARS MILLIONS	WEIGHT MLN LBS	WASTE MLN LBS	HEAT BLN BTUS
1967	49.0	98.0	0.0	0.0
B-HI				
1980	85.2	170.4	0.0	0.0
1990	134.4	268.8	0.0	0.0
E-LO				
1980	72.5	145.1	0.0	0.0
1990	99.6	199.2	0.0	0.0

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BUYER    99 - MSC FBRCTD WIRE PRDS                                                  PAGE 1

                   DOLLARS        WEIGHT       W/C        WASTE      H/C         HEAT
                   MILLIONS       MLN LBS                 MLN LBS               BLN BTUS

SELLER   37 - MISC TEXTILES*

     1967           47.00          281.9      0.040        11.28     12.5        140.95

B-HI
     1980           71.98          431.8      0.040        17.28     12.5        215.88
     1990          100.15          600.7      0.040        24.03     12.5        300.33
E-LO
     1980           65.74          394.3      0.040        15.78     12.5        197.16
     1990           83.40          500.2      0.040        20.02     12.5        250.12

TOTALS

     1967           47.0           281.9                   11.3                  140.9

B-HI
     1980           72.0           431.8                   17.3                  215.9
     1990          100.1           600.7                   24.0                  300.3
E-LO
     1980           65.7           394.3                   15.8                  197.2
     1990           83.4           500.2                   20.0                  250.1
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BUYER 103 - FARM MACHINERY PAGE 1

	DOLLARS MILLIONS	WEIGHT MLN LBS	W/C	WASTE MLN LBS	H/C	HEAT BLN BTUS
SELLER 72 - TIRES & INNER TUBES						
1967	99.22	285.5	0.000	0.00	0.0	0.00
B-HI						
1980	132.80	382.1	0.000	0.00	0.0	0.00
1990	174.58	502.3	0.000	0.00	0.0	0.00
E-LO						
1980	123.98	356.7	0.000	0.00	0.0	0.00
1990	146.77	422.3	0.000	0.00	0.0	0.00
SELLER 73 - RUBBER PRODUCTS						
1967	14.33	5.5	0.051	0.28	9.9	2.76
B-HI						
1980	19.18	7.4	0.051	0.37	9.9	3.69
1990	25.21	9.7	0.051	0.49	9.9	4.86
E-LO						
1980	17.91	6.9	0.051	0.35	9.9	3.45
1990	21.20	8.2	0.051	0.41	9.9	4.08
TOTALS						
1967	113.5	291.0		0.3		2.8
B-HI						
1980	152.0	389.5		0.4		3.7
1990	199.8	512.0		0.5		4.9
E-LO						
1980	141.9	363.6		0.3		3.4
1990	168.0	430.4		0.4		4.1

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BUYER    104 - CNST,MNNG&0IL FLDMAC                                                  PAGE 1
                      D0LLARS        WEIGHT        W/C        WASTE        H/C        HEAT
                      MILLI0NS       MLN LBS                  MLN LBS                 BLN BTUS

SELLER    72 - TIRES & INNER TUBES

     1967              69.92          14.0       0.000         0.00        0.0        0.00

B-HI
     1980              97.09          19.4       0.000         0.00        0.0        0.00
     1990             125.76          25.1       0.000         0.00        0.0        0.00
E-L0
     1980              89.92          18.0       0.000         0.00        0.0        0.00
     1990             107.44          21.5       0.000         0.00        0.0        0.00

T0TALS

     1967               69.9          14.0                      0.0                   0.0

B-HI
     1980               97.1          19.4                      0.0                   0.0
     1990              125.8          25.1                      0.0                   0.0
E-L0
     1980               89.9          18.0                      0.0                   0.0
     1990              107.4          21.5                      0.0                   0.0
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BUYER   105 - MTRLS HNDLNG MACHNRY                                   PAGE 1

                  DOLLARS     WEIGHT      W/C        WASTE      H/C       HEAT
                 MILLIONS    MLN LBS               MLN LBS             BLN BTUS

SELLER   72 - TIRES & INNER TUBES

    1967          33.00       229.5     0.000        0.00      0.0       0.00

B-HI
    1980          40.07       278.7     0.000        0.00      0.0       0.00
    1990          55.29       384.5     0.000        0.00      0.0       0.00
E-LO
    1980          37.58       261.4     0.000        0.00      0.0       0.00
    1990          48.22       335.4     0.000        0.00      0.0       0.00

TOTALS

    1967          33.0        229.5                   0.0                 0.0

B-HI
    1980          40.1        278.7                   0.0                 0.0
    1990          55.3        384.5                   0.0                 0.0
E-LO
    1980          37.6        261.4                   0.0                 0.0
    1990          48.2        335.4                   0.0                 0.0
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BUYER   123 - HOUSEHOLD APPLIANCES                                  PAGE 1

                  DOLLARS      WEIGHT      W/C       WASTE      H/C       HEAT
                 MILLIONS     MLN LBS               MLN LBS             BLN BTUS

SELLER   45 - HOUSEHOLD FURNITURE

     1967           58.23        82.7   0.000         0.00      0.0        0.00

B-HI
     1980          117.36       166.6   0.000         0.00      0.0        0.00
     1990          218.88       310.7   0.000         0.00      0.0        0.00
E-L0
     1980          100.74       143.0   0.000         0.00      0.0        0.00
     1990          162.82       231.1   0.000         0.00      0.0        0.00

SELLER   74 - MISC PLSTC PRODS

     1967          229.00       467.0   0.000         0.00      0.0        0.00

B-HI
     1980          461.53       941.2   0.000         0.00      0.0        0.00
     1990          860.80      1755.4   0.000         0.00      0.0        0.00
E-L0
     1980          396.19       807.9   0.000         0.00      0.0        0.00
     1990          640.31      1305.8   0.000         0.00      0.0        0.00

TOTALS

     1967           287.2       549.7                  0.0                  0.0

B-HI
     1980           578.9      1107.8                  0.0                  0.0
     1990          1079.7      2066.1                  0.0                  0.0
E-L0
     1980           496.9       951.0                  0.0                  0.0
     1990           803.1      1536.9                  0.0                  0.0
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BUYER 124 - ELEC LTGNG&WIRNG EQP

	DOLLARS MILLIONS	WEIGHT MLN LBS	W/C	WASTE MLN LBS	H/C	HEAT BLN BTUS
SELLER 62 - PLSTC MATRLS & RESNS						
1967	26.96	74.4	0.022	1.63	12.6	20.46
B-HI						
1980	45.48	125.5	0.022	2.75	12.6	34.51
1990	66.28	182.9	0.022	4.01	12.6	50.30
E-LO						
1980	40.36	111.4	0.022	2.44	12.6	30.63
1990	53.24	146.9	0.022	3.22	12.6	40.40
SELLER 74 - MISC PLSTC PRODS						
1967	114.00	233.0	0.000	0.00	0.0	0.00
B-HI						
1980	192.29	393.0	0.000	0.00	0.0	0.00
1990	280.28	572.9	0.000	0.00	0.0	0.00
E-LO						
1980	170.65	348.8	0.000	0.00	0.0	0.00
1990	225.13	460.1	0.000	0.00	0.0	0.00
TOTALS						
1967	141.0	307.4		1.6		20.5
B-HI						
1980	237.8	518.5		2.7		34.5
1990	346.6	755.8		4.0		50.3
E-LO						
1980	211.0	460.2		2.4		30.6
1990	278.4	607.1		3.2		40.4

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BUYER   125 - RADI0 & TV RECEIVING

                  D0LLARS      WEIGHT     W/C         WASTE      H/C       HEAT
                  MILLI0NS     MLN LBS                MLN LBS              BLN BTUS
SELLER   45 - H0USEH0LD FURNITURE

     1967         307.98       1054.5    0.000        0.00       0.0       0.00

B-HI
     1980         539.24       1846.4    0.000        0.00       0.0       0.00
     1990         462.01       1582.0    0.000        0.00       0.0       0.00
E-L0
     1980         528.88       1810.9    0.000        0.00       0.0       0.00
     1990         434.50       1487.7    0.000        0.00       0.0       0.00

SELLER   74 - MISC PLSTC PR0DS

     1967          63.79        129.8    0.000        0.00       0.0       0.00

B-HI
     1980         111.69        227.2    0.000        0.00       0.0       0.00
     1990          95.69        194.7    0.000        0.00       0.0       0.00
E-L0
     1980         109.54        222.9    0.000        0.00       0.0       0.00
     1990          89.99        183.1    0.000        0.00       0.0       0.00

T0TALS

     1967         371.8        1184.3                 0.0                  0.0

B-HI
     1980         650.9        2073.6                 0.0                  0.0
     1990         557.7        1776.7                 0.0                  0.0
E-L0
     1980         638.4        2033.8                 0.0                  0.0
     1990         524.5        1670.8                 0.0                  0.0
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BUYER 127 - COMMUNICATION EQUIP

	DOLLARS MILLIONS	WEIGHT MLN LBS	W/C	WASTE MLN LBS	H/C	HEAT BLN BTUS
SELLER 62 - PLSTC MATRLS & RESNS						
1967	12.41	34.1	0.022	0.75	12.5	9.38
B-HI						
1980	13.78	37.9	0.022	0.83	12.5	10.42
1990	18.42	50.6	0.022	1.11	12.5	13.93
E-LO						
1980	13.22	36.3	0.022	0.80	12.5	9.99
1990	16.51	45.4	0.022	1.00	12.5	12.48
TOTALS						
1967	12.4	34.1		0.7		9.4
B-HI						
1980	13.8	37.9		0.8		10.4
1990	18.4	50.6		1.1		13.9
E-LO						
1980	13.2	36.3		0.8		10.0
1990	16.5	45.4		1.0		12.5

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BUYER   128 - ELECTRONIC CMPONENTS                                PAGE 1

                DOLLARS      WEIGHT      W/C       WASTE      H/C      HEAT
               MILLIONS     MLN LBS              MLN LBS             BLN BTUS

SELLER   49 - PAPER PROD, NEC

     1967        70.00        282.0    0.000        0.00      0.0       0.00

B-HI
     1980       108.34        436.4    0.000        0.00      0.0       0.00
     1990       136.28        549.0    0.000        0.00      0.0       0.00
E-LO
     1980       103.09        415.3    0.000        0.00      0.0       0.00
     1990       119.11        479.8    0.000        0.00      0.0       0.00

SELLER   62 - PLSTC MATRLS & RESNS

     1967        16.00         18.0    0.022        0.40     12.4       4.95

B-HI
     1980        24.76         27.9    0.022        0.62     12.4       7.66
     1990        31.15         35.0    0.022        0.78     12.4       9.64
E-LO
     1980        23.56         26.5    0.022        0.59     12.4       7.29
     1990        27.22         30.6    0.022        0.68     12.4       8.42

SELLER   74 - MISC PLSTC PRODS

     1967       234.00        478.0    0.000        0.00      0.0       0.00

B-HI
     1980       362.15        739.8    0.000        0.00      0.0       0.00
     1990       455.56        930.6    0.000        0.00      0.0       0.00
E-LO
     1980       344.60        703.9    0.000        0.00      0.0       0.00
     1990       398.15        813.3    0.000        0.00      0.0       0.00

TOTALS

     1967        320.0        778.0                  0.4                 5.0

B-HI
     1980        495.3       1204.1                  0.6                 7.7
     1990        623.0       1514.6                  0.8                 9.6
E-LO
     1980        471.2       1145.7                  0.6                 7.3
     1990        544.5       1323.8                  0.7                 8.4
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BUYER   129 - BATTERIES                                                 PAGE 1

                    DOLLARS      WEIGHT      W/C        WASTE      H/C       HEAT
                   MILLIONS     MLN LBS                MLN LBS             BLN BTUS

SELLER    73 - RUBBER PRODUCTS

     1967            40.00        40.0     0.050          2.00     10.0       20.00

B-HI
     1980            57.80        57.8     0.050          2.89     10.0       28.90
     1990            72.10        72.1     0.050          3.61     10.0       36.05
E-LO
     1980            54.63        54.6     0.050          2.73     10.0       27.32
     1990            62.34        62.3     0.050          3.12     10.0       31.17

TOTALS

     1967             40.0        40.0                     2.0                 20.0

B-HI
     1980             57.8        57.8                     2.9                 28.9
     1990             72.1        72.1                     3.6                 36.1
E-LO
     1980             54.6        54.6                     2.7                 27.3
     1990             62.3        62.3                     3.1                 31.2
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BUYER 132 - TRK,BUS,&TRLR BODYS PAGE 1

	DOLLARS MILLIONS	WEIGHT MLN LBS	W/C	WASTE MLN LBS	H/C	HEAT BLN BTUS
SELLER 35 - BROAD & NARROW FBRCS						
1967	0.12	2.6	0.039	0.10	7.8	0.78
B-HI						
1980	0.15	3.3	0.039	0.13	7.8	0.99
1990	0.22	4.7	0.039	0.18	7.8	1.42
E-LO						
1980	0.14	3.0	0.039	0.12	7.8	0.90
1990	0.18	3.8	0.039	0.15	7.8	1.15
SELLER 37 - MISC TEXTILES*						
1967	1.06	229.2	0.040	9.17	7.5	68.76
B-HI						
1980	1.34	290.3	0.040	11.61	7.5	87.08
1990	1.93	417.7	0.040	16.71	7.5	125.32
E-LO						
1980	1.22	264.4	0.040	10.58	7.5	79.32
1990	1.57	339.0	0.040	13.56	7.5	101.69
SELLER 62 - PLSTC MATRLS & RESNS						
1967	0.00	4.0	0.020	0.08	13.9	1.11
B-HI						
1980	0.00	5.1	0.020	0.10	13.9	1.41
1990	0.00	7.3	0.020	0.15	13.9	2.02
E-LO						
1980	0.00	4.6	0.020	0.09	13.9	1.28
1990	0.00	5.9	0.020	0.12	13.9	1.64
TOTALS						
1967	1.2	235.8		9.3		70.6
B-HI						
1980	1.5	298.6		11.8		89.5
1990	2.2	429.8		17.0		128.8
E-LO						
1980	1.4	272.0		10.8		81.5
1990	1.7	348.7		13.8		104.5

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BUYER   133 - MTR VEHICLES & PARTS                                       PAGE 1

                   DOLLARS        WEIGHT      W/C        WASTE      H/C        HEAT
                  MILLIONS       MLN LBS                MLN LBS              BLN BTUS

SELLER   37 - MISC TEXTILES*

     1967            8.86           5.2     0.040          0.21      7.5         1.57

B-HI
     1980           14.52           8.6     0.040          0.34      7.5         2.57
     1990           20.81          12.3     0.040          0.49      7.5         3.69
E-LO
     1980           13.82           8.2     0.040          0.33      7.5         2.45
     1990           18.22          10.8     0.040          0.43      7.5         3.23

SELLER   40 - HOUSEHOLD TEXTILES*

     1967         1169.86        5560.4     0.040        222.41      9.9      2202.25

B-HI
     1980         1917.82        9115.5     0.040        364.61      9.9      3610.28
     1990         2748.11       13061.9     0.040        522.46      9.9      5173.29
E-LO
     1980         1824.95        8674.0     0.040        346.95      9.9      3435.45
     1990         2405.63       11434.0     0.040        457.35      9.9      4528.57

SELLER   62 - PLSTC MATRLS & RESNS

     1967           23.98          75.0     0.022          1.65     12.5        20.64

B-HI
     1980           39.31         123.0     0.022          2.70     12.5        33.84
     1990           56.33         176.3     0.022          3.88     12.5        48.49
E-LO
     1980           37.41         117.1     0.022          2.57     12.5        32.20
     1990           49.31         154.3     0.022          3.39     12.5        42.44

SELLER   72 - TIRES & INNER TUBES

     1967         3058.38        6845.7     0.000          0.00      0.0         0.00

B-HI
     1980         5013.78       11222.6     0.000          0.00      0.0         0.00
     1990         7184.42       16081.2     0.000          0.00      0.0         0.00
E-LO
     1980         4770.99       10679.1     0.000          0.00      0.0         0.00
     1990         6289.07       14077.1     0.000          0.00      0.0         0.00

SELLER   73 - RUBBER PRODUCTS

     1967          354.40         341.9     0.050         17.09     10.0       170.94

B-HI
     1980          580.99         560.5     0.050         28.02     10.0       280.23
     1990          832.52         803.2     0.050         40.15     10.0       401.55
E-LO
     1980          552.85         533.4     0.050         26.66     10.0       266.66
     1990          728.77         703.1     0.050         35.14     10.0       351.51
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BUYER   133 - MTR VEHICLES & PARTS                                    PAGE 2

                 DOLLARS      WEIGHT       W/C        WASTE      H/C       HEAT
                 MILLIONS     MLN LBS                 MLN LBS              BLN BTUS

SELLER   74 - MISC PLSTC PRODS

    1967          669.05       1568.0     0.006          9.45     12.5      118.11

B-HI
    1980         1096.81       2570.5     0.006         15.49     12.5      193.62
    1990         1571.66       3683.4     0.006         22.20     12.5      277.45
E-LO
    1980         1043.70       2446.1     0.006         14.74     12.5      184.25
    1990         1375.79       3224.4     0.006         19.43     12.5      242.87

TOTALS

    1967          5284.5      14396.3                   250.8               2513.5

B-HI
    1980          8663.2      23600.7                   411.2               4120.5
    1990         12413.9      33818.3                   589.2               5904.5
E-LO
    1980          8243.7      22457.8                   391.3               3921.0
    1990         10866.8      29603.7                   515.8               5168.6
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BUYER    134 - AIRCRAFT                                                      PAGE 1

                      DOLLARS       WEIGHT       W/C        WASTE       H/C        HEAT
                      MILLIONS      MLN LBS                 MLN LBS               BLN BTUS

SELLER    72 - TIRES & INNER TUBES

      1967              54.00         27.0     0.000          0.00       0.0        0.00

B-HI
      1980              60.65         30.3     0.000          0.00       0.0        0.00
      1990              84.39         42.2     0.000          0.00       0.0        0.00
E-LO
      1980              57.90         29.0     0.000          0.00       0.0        0.00
      1990              74.76         37.4     0.000          0.00       0.0        0.00

SELLER    74 - MISC PLSTC PRODS

      1967              58.00        157.0     0.011          1.73      12.5       21.59

B-HI
      1980              65.14        176.3     0.011          1.94      12.5       24.25
      1990              90.64        245.3     0.011          2.70      12.5       33.74
E-LO
      1980              62.19        168.4     0.011          1.86      12.5       23.15
      1990              80.30        217.4     0.011          2.40      12.5       29.89

TOTALS

      1967              112.0        184.0                    1.7                  21.6

B-HI
      1980              125.8        206.7                    1.9                  24.2
      1990              175.0        287.5                    2.7                  33.7
E-LO
      1980              120.1        197.3                    1.9                  23.2
      1990              155.1        254.7                    2.4                  29.9
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BUYER 137 - SHP,BOT BLDG EQP&RPR

	DOLLARS MILLIONS	WEIGHT MLN LBS	W/C	WASTE MLN LBS	H/C	HEAT BLN BTUS
SELLER 40 - HOUSEHOLD TEXTILES*						
1967	31.80	192.0	0.040	7.68	10.0	76.80
B-HI						
1980	37.37	225.7	0.040	9.03	10.0	90.26
1990	52.24	315.4	0.040	12.62	10.0	126.15
E-LO						
1980	37.03	223.6	0.040	8.94	10.0	89.42
1990	49.40	298.2	0.040	11.93	10.0	119.30
SELLER 41 - LMBR & WOOD PRODUCTS						
1967	6.00	92.4	0.072	6.65	10.0	66.53
B-HI						
1980	7.05	108.6	0.072	7.82	10.0	78.19
1990	9.86	151.8	0.072	10.92	10.0	109.28
E-LO						
1980	6.99	107.6	0.072	7.74	10.0	77.46
1990	9.32	143.5	0.072	10.33	10.0	103.35
SELLER 62 - PLSTC MATRLS & RESNS						
1967	9.00	38.0	0.022	0.84	12.4	10.45
B-HI						
1980	10.58	44.7	0.022	0.99	12.4	12.28
1990	14.78	62.4	0.022	1.38	12.4	17.17
E-LO						
1980	10.48	44.2	0.022	0.98	12.4	12.17
1990	13.98	59.0	0.022	1.30	12.4	16.23
TOTALS						
1967	46.8	322.4		15.2		153.8
B-HI						
1980	55.0	378.9		17.8		180.7
1990	76.9	529.6		24.9		252.6
E-LO						
1980	54.5	375.4		17.7		179.1
1990	72.7	500.8		23.6		238.9

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BUYER   140 - TRAILER COACHES                                                    PAGE 1

                    DOLLARS       WEIGHT       W/C          WASTE       H/C        HEAT
                   MILLIONS      MLN LBS                   MLN LBS               BLN BTUS

SELLER    41 - LMBR & WOOD PRODUCTS

     1967             68.33       2064.4     0.072          148.64     10.0      1486.37

B-HI
     1980            116.17       3509.7     0.072          252.70     10.0      2526.97
     1990            172.31       5205.9     0.072          374.83     10.0      3748.23
E-LO
     1980            112.60       3401.8     0.072          244.93     10.0      2449.29
     1990            154.02       4653.3     0.072          335.05     10.0      3350.40

SELLER    43 - MILLWORK & WOOD PROD

     1967            118.43        236.9     0.000            0.00      0.0         0.00

B-HI
     1980            201.34        402.7     0.000            0.00      0.0         0.00
     1990            298.65        597.3     0.000            0.00      0.0         0.00
E-LO
     1980            195.15        390.3     0.000            0.00      0.0         0.00
     1990            266.95        533.9     0.000            0.00      0.0         0.00

TOTALS

     1967             186.8       2301.3                     148.6                1486.4

B-HI
     1980             317.5       3912.4                     252.7                2527.0
     1990             471.0       5803.2                     374.8                3748.2
E-LO
     1980             307.7       3792.1                     244.9                2449.3
     1990             421.0       5187.2                     335.0                3350.4
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BUYER   144 - MDCL & SURGCL INSTRS                                              PAGE 1
                  DOLLARS      WEIGHT       W/C        WASTE      H/C        HEAT
                  MILLIONS     MLN LBS                 MLN LBS               BLN BTUS

SELLER   35 - BROAD & NARROW FBRCS

    1967           67.50        156.9      0.040        6.27      10.0        62.75

B-HI
    1980          164.66        382.7      0.040       15.29      10.0       153.07
    1990          305.22        709.4      0.040       28.35      10.0       283.74
E-LO
    1980          151.27        351.6      0.040       14.05      10.0       140.62
    1990          256.75        596.7      0.040       23.85      10.0       238.68

TOTALS

    1967           67.5         156.9                   6.3                   62.8

B-HI
    1980          164.7         382.7                  15.3                  153.1
    1990          305.2         709.4                  28.4                  283.7
E-LO
    1980          151.3         351.6                  14.1                  140.6
    1990          256.7         596.7                  23.8                  238.7
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BUYER 145 - PHOTO EQUIPMENT

SELLER 48 - PAPER & PPRBRD MILLS

	DOLLARS MILLIONS	WEIGHT MLN LBS	W/C	WASTE MLN LBS	H/C	HEAT BLN BTUS
1967	116.00	58.0	0.040	2.32	7.5	17.40
B-HI						
1980	192.77	96.4	0.040	3.86	7.5	28.91
1990	269.41	134.7	0.040	5.39	7.5	40.41
E-LO						
1980	187.20	93.6	0.040	3.74	7.5	28.08
1990	247.06	123.5	0.040	4.94	7.5	37.06
TOTALS						
1967	116.0	58.0		2.3		17.4
B-HI						
1980	192.8	96.4		3.9		28.9
1990	269.4	134.7		5.4		40.4
E-LO						
1980	187.2	93.6		3.7		28.1
1990	247.1	123.5		4.9		37.1

BUYER 147 - JEWELRY & SILVERWARE

	DOLLARS MILLIONS	WEIGHT MLN LBS	W/C	WASTE MLN LBS	H/C	HEAT BLN BTUS
SELLER 74 - MISC PLSTC PRODS						
1967	56.00	114.0	0.000	0.00	0.0	0.00
B-HI						
1980	107.26	218.4	0.000	0.00	0.0	0.00
1990	157.81	321.3	0.000	0.00	0.0	0.00
E-LO						
1980	101.62	206.9	0.000	0.00	0.0	0.00
1990	134.83	274.5	0.000	0.00	0.0	0.00
TOTALS						
1967	56.0	114.0		0.0		0.0
B-HI						
1980	107.3	218.4		0.0		0.0
1990	157.8	321.3		0.0		0.0
E-LO						
1980	101.6	206.9		0.0		0.0
1990	134.8	274.5		0.0		0.0

BUYER 148 - TOYS, SPTNG GD&MUSICL

	DOLLARS MILLIONS	WEIGHT MLN LBS	W/C	WASTE MLN LBS	H/C	HEAT BLN BTUS
SELLER 37 - MISC TEXTILES*						
1967	44.76	268.6	0.040	10.74	12.5	134.29
B-HI						
1980	75.90	455.4	0.040	18.21	12.5	227.73
1990	125.82	754.9	0.040	30.19	12.5	377.48
E-LO						
1980	76.61	459.7	0.040	18.38	12.5	229.85
1990	114.24	685.5	0.040	27.41	12.5	342.76
SELLER 62 - PLSTC MATRLS & RESNS						
1967	50.28	274.7	0.022	6.04	12.5	75.54
B-HI						
1980	85.26	465.8	0.022	10.24	12.5	128.10
1990	141.33	772.2	0.022	16.98	12.5	212.34
E-LO						
1980	86.06	470.2	0.022	10.34	12.5	129.30
1990	128.33	701.1	0.022	15.42	12.5	192.80
SELLER 74 - MISC PLSTC PRODS						
1967	145.00	295.0	0.000	0.00	0.0	0.00
B-HI						
1980	245.89	500.3	0.000	0.00	0.0	0.00
1990	407.59	829.2	0.000	0.00	0.0	0.00
E-LO						
1980	248.19	504.9	0.000	0.00	0.0	0.00
1990	370.09	752.9	0.000	0.00	0.0	0.00
TOTALS						
1967	240.0	838.3		16.8		209.8
B-HI						
1980	407.1	1421.5		28.5		355.8
1990	674.7	2356.3		47.2		589.3
E-LO						
1980	410.9	1434.8		28.7		359.1
1990	612.7	2139.6		42.8		535.6

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BUYER   150 - MISC MANUF, NEC                                                    PAGE 1

                    DOLLARS      WEIGHT     W/C        WASTE       H/C        HEAT
                    MILLIONS     MLN LBS               MLN LBS               BLN BTUS

SELLER   35 - BROAD & NARROW FBRCS

     1967             58.10       134.9    0.040         5.39      10.0         53.95

B-HI
     1980             87.28       202.6    0.040         8.10      10.0         81.05
     1990            125.93       292.3    0.040        11.68      10.0        116.93
E-LO
     1980             81.16       188.4    0.040         7.53      10.0         75.36
     1990            105.98       246.0    0.040         9.83      10.0         98.41

SELLER   43 - MILLWORK & WOOD PROD

     1967             56.00       112.0    0.000         0.00       0.0          0.00

B-HI
     1980             84.13       168.3    0.000         0.00       0.0          0.00
     1990            121.37       242.7    0.000         0.00       0.0          0.00
E-LO
     1980             78.22       156.4    0.000         0.00       0.0          0.00
     1990            102.15       204.3    0.000         0.00       0.0          0.00

SELLER   62 - PLSTC MATRLS & RESNS

     1967            110.00       943.0    0.022        20.75      12.5        259.32

B-HI
     1980            165.25      1416.6    0.022        31.17      12.5        389.56
     1990            238.41      2043.8    0.022        44.97      12.5        562.05
E-LO
     1980            153.66      1317.3    0.022        28.99      12.5        362.24
     1990            200.66      1720.2    0.022        37.85      12.5        473.04

SELLER   74 - MISC PLSTC PRODS

     1967             62.00       126.0    0.000         0.00       0.0          0.00

B-HI
     1980             93.14       189.3    0.000         0.00       0.0          0.00
     1990            134.38       273.1    0.000         0.00       0.0          0.00
E-LO
     1980             86.61       176.0    0.000         0.00       0.0          0.00
     1990            113.10       229.8    0.000         0.00       0.0          0.00

TOTALS

     1967             286.1      1315.9                  26.1                   313.3

B-HI
     1980             429.8      1976.8                  39.3                   470.6
     1990             620.1      2852.0                  56.7                   679.0
E-LO
     1980             399.6      1838.1                  36.5                   437.6
     1990             521.9      2400.4                  47.7                   571.5
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BUYER 164 - RETAIL TRADE

	DOLLARS MILLIONS	WEIGHT MLN LBS	W/C	WASTE MLN LBS	H/C	HEAT BLN BTUS
SELLER 48 - PAPER & PPRBRD MILLS						
1967	103.00	517.0	0.040	20.68	7.5	155.10
B-HI						
1980	164.58	826.1	0.040	33.04	7.5	247.83
1990	226.14	1135.1	0.040	45.40	7.5	340.53
E-LO						
1980	155.26	779.3	0.040	31.17	7.5	233.80
1990	195.35	980.5	0.040	39.22	7.5	294.16
TOTALS						
1967	103.0	517.0		20.7		155.1
B-HI						
1980	164.6	826.1		33.0		247.8
1990	226.1	1135.1		45.4		340.5
E-LO						
1980	155.3	779.3		31.2		233.8
1990	195.3	980.5		39.2		294.2

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BUYER   172 - ADVERTISING
                                                                            PAGE 1
                 DOLLARS      WEIGHT       W/C        WASTE       H/C       HEAT
                 MILLIONS     MLN LBS                 MLN LBS               BLN BTUS
SELLER   52 - NEWSPAPER

      1967       4022.00        0.0      0.000         0.00       0.0        0.00
  B-HI
      1980       6597.64        0.0      0.000         0.00       0.0        0.00
      1990       9153.91        0.0      0.000         0.00       0.0        0.00
  E-LO
      1980       6253.94        0.0      0.000         0.00       0.0        0.00
      1990       7955.98        0.0      0.000         0.00       0.0        0.00
SELLER   53 - BKS,PRDCLS,&MSC PUBS

      1967       1610.00        0.0      0.000         0.00       0.0        0.00
  B-HI
      1980       2641.02        0.0      0.000         0.00       0.0        0.00
      1990       3664.30        0.0      0.000         0.00       0.0        0.00
  E-LO
      1980       2503.44        0.0      0.000         0.00       0.0        0.00
      1990       3184.77        0.0      0.000         0.00       0.0        0.00
TOTALS

      1967       5632.0         0.0                    0.0                   0.0
  B-HI
      1980       9238.7         0.0                    0.0                   0.0
      1990      12818.2         0.0                    0.0                   0.0
  E-LO
      1980       8757.4         0.0                    0.0                   0.0
      1990      11140.7         0.0                    0.0                   0.0
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BUYER   201 - RSDNTL,FRM,MSC HSNG                                         PAGE 1

                  DOLLARS      WEIGHT      W/C        WASTE       H/C       HEAT
                 MILLIONS     MLN LBS                MLN LBS              BLN BTUS

SELLER   41 - LMBR & WOOD PRODUCTS

     1967          639.60     15621.0    0.075       1171.50     10.0    11715.00

B-HI
     1980         1283.93     31357.6    0.075       2351.67     10.0    23516.73
     1990         1841.15     44966.6    0.075       3372.28     10.0    33722.81
E-LO
     1980         1190.64     29079.1    0.075       2180.80     10.0    21807.96
     1990         1521.99     37171.6    0.075       2787.69     10.0    27876.94

SELLER   43 - MILLWORK & WOOD PROD

     1967          989.00      1878.0    0.075        140.85     10.0     1408.50

B-HI
     1980         1985.32      3769.9    0.075        282.74     10.0     2827.43
     1990         2846.94      5406.0    0.075        405.45     10.0     4054.51
E-LO
     1980         1841.06      3496.0    0.075        262.20     10.0     2621.98
     1990         2353.42      4468.9    0.075        335.17     10.0     3351.66

SELLER   50 - WALL & BLDG PAPER

     1967           38.00       305.0    0.060         18.30      7.5      137.25

B-HI
     1980           76.28       612.3    0.060         36.74      7.5      275.52
     1990          109.39       878.0    0.060         52.68      7.5      395.09
E-LO
     1980           70.74       567.8    0.060         34.07      7.5      255.50
     1990           90.42       725.8    0.060         43.55      7.5      326.60

TOTALS

     1967          1666.6     17804.0                 1330.6              13260.8

B-HI
     1980          3345.5     35739.8                 2671.2              26619.7
     1990          4797.5     51250.6                 3830.4              38172.4
E-LO
     1980          3102.4     33142.9                 2477.1              24685.4
     1990          3965.8     42366.3                 3166.4              31555.2
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BUYER   202 - AD&ALTR,MSC-N-BD CST                                          PAGE 1

                   DOLLARS      WEIGHT      W/C        WASTE      H/C        HEAT
                   MILLIONS     MLN LBS               MLN LBS               BLN BTUS

SELLER   41 - LMBR & WOOD PRODUCTS

     1967          145.90       3106.0     0.125       388.20     10.0      3882.00

B-HI
     1980          180.74       3847.7     0.125       480.91     10.0      4809.06
     1990          245.48       5226.0     0.125       653.16     10.0      6531.60
E-LO
     1980          180.74       3847.7     0.125       480.91     10.0      4809.06
     1990          245.48       5226.0     0.125       653.16     10.0      6531.60

SELLER   43 - MILLWORK & WOOD PROD

     1967          372.00        745.0     0.075        55.87     10.0       558.75

B-HI
     1980          460.84        922.9     0.075        69.21     10.0       692.18
     1990          625.90       1253.5     0.075        94.00     10.0       940.12
E-LO
     1980          460.84        922.9     0.075        69.21     10.0       692.18
     1990          625.90       1253.5     0.075        94.00     10.0       940.12

TOTALS

     1967           517.9       3851.0                  444.1                4440.8

B-HI
     1980           641.6       4770.7                  550.1                5501.2
     1990           871.4       6479.4                  747.2                7471.7
E-LO
     1980           641.6       4770.7                  550.1                5501.2
     1990           871.4       6479.4                  747.2                7471.7
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BUYER   203 - COMMERCIAL CONSTR
                                                                                PAGE 1
                  DOLLARS        WEIGHT       W/C         WASTE        H/C        HEAT
                  MILLIONS       MLN LBS                  MLN LBS                 BLN BTUS

SELLER    50 - WALL & BLDG PAPER

     1967          23.00          184.0     0.060          11.04       7.5         82.80

B-HI
     1980          34.24          273.9     0.060          16.44       7.5        123.28
     1990          49.88          399.0     0.060          23.94       7.5        179.55
E-LO
     1980          33.35          266.8     0.060          16.01       7.5        120.05
     1990          47.03          376.2     0.060          22.57       7.5        169.30

TOTALS

     1967          23.0           184.0                    11.0                    82.8

B-HI
     1980          34.2           273.9                    16.4                   123.3
     1990          49.9           399.0                    23.9                   179.6
E-LO
     1980          33.3           266.8                    16.0                   120.1
     1990          47.0           376.2                    22.6                   169.3
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BUYER   204 - PUBLIC UTILITY CONST                                              PAGE 1

                   DOLLARS      WEIGHT       W/C        WASTE       H/C        HEAT
                   MILLIONS     MLN LBS                 MLN LBS                BLN BTUS

SELLER   41 - LMBR & WOOD PRODUCTS

    1967           138.10       4963.0      0.085       421.80      10.0       4218.00

B-HI
    1980           166.75       5992.7      0.085       509.32      10.0       5093.15
    1990           141.51       5085.4      0.085       432.21      10.0       4322.05
E-LO
    1980           130.80       4700.6      0.085       399.50      10.0       3995.03
    1990           138.96       4994.0      0.085       424.44      10.0       4244.35

SELLER   43 - MILLWORK & WOOD PROD

    1967           193.00        385.0      0.075        28.87      10.0        288.75

B-HI
    1980           233.04        464.9      0.075        34.86      10.0        348.66
    1990           197.76        394.5      0.075        29.58      10.0        295.87
E-LO
    1980           182.80        364.6      0.075        27.34      10.0        273.49
    1990           194.21        387.4      0.075        29.05      10.0        290.55

TOTALS

    1967            331.1       5348.0                   450.7                 4506.8

B-HI
    1980            399.8       6457.6                   544.2                 5441.8
    1990            339.3       5479.9                   461.8                 4617.9
E-LO
    1980            313.6       5065.3                   426.8                 4268.5
    1990            333.2       5381.4                   453.5                 4534.9
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BUYER   205 - INSTNL,OFC BLDG CNST                                    PAGE 1

                  DOLLARS      WEIGHT     W/C        WASTE      H/C        HEAT
                  MILLIONS     MLN LBS               MLN LBS               BLN BTUS

SELLER   41 - LMBR & WOOD PRODUCTS

     1967           97.30      1261.2    0.085        107.20     10.0      1072.00

B-HI
     1980          202.92      2630.2    0.085        223.57     10.0      2235.66
     1990          297.88      3861.1    0.085        328.19     10.0      3281.91
E-LO
     1980          191.85      2486.7    0.085        211.37     10.0      2113.65
     1990          278.29      3607.2    0.085        306.61     10.0      3066.10

SELLER   43 - MILLWORK & WOOD PROD

     1967          162.00       324.0    0.075         24.30     10.0       243.00

B-HI
     1980          337.85       675.7    0.075         50.68     10.0       506.78
     1990          495.96       991.9    0.075         74.39     10.0       743.94
E-LO
     1980          319.41       638.8    0.075         47.91     10.0       479.12
     1990          463.35       926.7    0.075         69.50     10.0       695.02

SELLER   50 - WALL & BLDG PAPER

     1967           33.00       260.0    0.060         15.60      7.5       117.00

B-HI
     1980           68.82       542.2    0.060         32.53      7.5       244.00
     1990          101.03       796.0    0.060         47.76      7.5       358.19
E-LO
     1980           65.07       512.6    0.060         30.76      7.5       230.69
     1990           94.39       743.6    0.060         44.62      7.5       334.64

TOTALS

     1967          292.3       1845.2                 147.1                1432.0

B-HI
     1980          609.6       3848.2                 306.8                2986.4
     1990          894.9       5649.0                 450.3                4384.0
E-LO
     1980          576.3       3638.2                 290.0                2823.5
     1990          836.0       5277.6                 420.7                4095.8
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BUYER   206 - INDSTRL CONSTRUCTION
                                                                          PAGE 1
                 DOLLARS      WEIGHT      W/C        WASTE      H/C        HEAT
                 MILLIONS     MLN LBS               MLN LBS              BLN BTUS
SELLER   41 - LMBR & WOOD PRODUCTS

     1967         19.50        359.0     0.085       30.50      10.0      305.00

B-HI
     1980         26.22        482.7     0.085       41.01      10.0      410.07
     1990         36.98        680.9     0.085       57.85      10.0      578.46
E-LO
     1980         26.22        482.7     0.085       41.01      10.0      410.07
     1990         36.98        680.8     0.085       57.84      10.0      578.41

SELLER   50 - WALL & BLDG PAPER

     1967         26.00        206.0     0.060       12.36       7.5       92.70

B-HI
     1980         34.96        277.0     0.060       16.62       7.5      124.63
     1990         49.31        390.7     0.060       23.44       7.5      175.81
E-LO
     1980         34.96        277.0     0.060       16.62       7.5      124.63
     1990         49.31        390.7     0.060       23.44       7.5      175.80

TOTALS

     1967          45.5        565.0                  42.9                397.7

B-HI
     1980          61.2        759.6                  57.6                534.7
     1990          86.3       1071.6                  81.3                754.3
E-LO
     1980          61.2        759.6                  57.6                534.7
     1990          86.3       1071.5                  81.3                754.2
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APPENDIX B

URBAN REFUSE AND SEWAGE

Appendix B is a summary of urban generated waste, divided into the following general classes:

1. Household and Municipal Waste
2. Sewage Sludge
3. Commercial and Institutional Waste

CSW generated as a result of Commercial and Institutional activity was further divided into a General Office Sector, a Public Schools Sector, a Hospital Sector, a Wholesale and Retail Trade Sector, and a Restaurant Sector. These five sources account for Commercial and Institutional Waste.

The waste from Household and Municipal and Commercial and Institutional Sectors is broken down into natural and synthetic fractions.

The geographical regions on which waste-generating sources is based are SMSA's. Because metropolitan areas implicitly define waste generating areas, and because it is expected that CSW resource-extractive efforts will be organized around something like metropolitan areas, it was felt that SMSA's would be the most meaningful geographical unit on which to base the analysis.

Household and Municipal, Sewage Sludge, Schools and Hospital Sector wasteloads were also determined on the basis of two larger geographical regions, 25 urban zones, and 9 larger metropolitan regions.

Wasteloads are projected for years 1980 and 1990, in addition to the base year 1970. The conditions for projections in each sector are discussed in the text below.

HOUSEHOLD AND MUNICIPAL WASTE GENERATION; SEWAGE SLUDGE

The projections of household and municipal waste in this report are based on average per capita collection figures for urban areas from the 1968 National Survey of Community Solid Waste Practices. However, since the figures published in the Interim Report in 1970 are based on incomplete processing of the returns, current figures, based on approximately 90% of the completed returns, were obtained from Paul Britton of the Statistical Services Section of the Office of Solid Waste Management. These per capita averages were computed on the

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basis that non-reporting communities generate the particular type of waste at the same rate as reporting communities.

The broad scope and coverage of the National Survey makes it, in general, much more reliable than local or small sample surveys. However, it does have certain shortcomings, deriving mainly from the fact the forms were completed by local officials without any supervision by OSWM personnel. Therefore, different localities may have defined some of the categories and types of wastes in different ways. Also, local officials cannot be expected to have accurate and complete knowledge of the amounts of waste collected or disposed of by private firms.

Definition of Municipal Waste - The following categories of waste were treated as part of the municipal sector: Household, Sewage Sludge, Street and Alley Cleanings, Tree and Landscaping, Park and Beach, Catch Basin Refuse. Commercial waste was designated as a separate sector because it is a weak point in the National Survey and because there is considerable variation among cities. To apply the same per capita rate over all cities would introduce an unacceptable error. Institutional waste is also being considered separately for similar reasons. Demolition and construction waste was left for future investigation as to whether it generates a significant amount of combustible waste material.

Composition of Municipal Wastes - It was necessary to break down Household waste into Combustible and Non-Combustible. Combustible was further divided into Natural and Synthetic Materials. Synthetic Combustibles include plastics, synthetic rubber, and synthetic fabrics. An analysis of Domestic Refuse, Santa Clara County, California, 1967, which was published in a report of the Office of Science and Technology, was used to determine waste composition. Since this analysis is based on five-year-old data, the percentage of plastics was increased from 1.0% to 1.5% to take into account the constantly increasing use of plastics in packaging, etc. It was also assumed that, of the 2% of domestic refuse which is cloth, approximately 60% represents man-made fabrics. (The reason for the classification into natural and synthetic is that this is the operative distinction as far as treatment by biological and chemical methods is concerned.) It was further assumed that 100% of rubber is synthetic rubber.

For 1970, this adds to a percentage breakdown for Household Waste of 74.8% Natural Combustibles and 3.3% Synthetic Combustibles, for a total of 78.1% Combustibles. Of the combustible portion, 95.7% is natural materials and 4.3% is synthetic materials.

The next task was to project the changing composition of Household waste for 1980 and 1990. It was assumed that plastics were the principal volatile component of concern and that changes in the relative proportions of paper, glass, and metal would be the result of the encroachment of plastics. An average annual growth rate of plastics production of about 15% per year was assumed (see *Plastic Wastes in the Coming Decade*, Environmental Protection Agency, 1971). A technological forecast determined that through 1980 new and expanded uses for plastics would come about 10% from paper and 90% from glass and metals. Through 1990, plastics encroachment will be about 30% from paper and 70% from glass and metals. This results in Table 100 (Projected Compositions of Household Waste).

TABLE 100

PROJECTED COMPOSITIONS OF HOUSEHOLD WASTE

	% of Hshld Waste that is Natural Combustibles		% of Hshld Waste that is Synthetic Combustibles	
1970	74.8	(95.7)	3.3	(4.3)
1980	75.7	(91.2)	7.3	(8.8)
1990	72.4	(80.4)	17.6	(19.5)

NOTE: The figures in parentheses represent the percentage of the combustible portion only.

One compositional change that was not dealt with is the substitution of paper and other packaging materials for food wastes. This is due to two factors: (1) increasing amounts of prepared foods and decreasing amounts of fresh foods are being consumed; (2) an increasing number of homes are equipped with garbage disposal units which dispose of food scraps directly to the sewage system. However, this substitution is mainly that of one organic combustible for another and is not, therefore, significant for our purposes.

After determing the probable future composition of household wastes, the next task was to determine the future per capita generation rates for each category of wastes. This was done in an *ad hoc* manner since there exist no time series data from which to construct a trend. Table 101 presents changes in the per capital generation rates from 1970.

There is some fragmented evidence that household waste is growing at about 2% per year. There is absolutely no evidence relating to street and alley wastes, but it may be supposed that generation of these wastes will continue to increase slightly due to increased congestion and affluence in the cities. Per capita amounts of tree and landscaping wastes are shown to be decreasing. This is due to the fact that population is increasing but the number of treees is not. Park and beach and catch basin wastes are shown to increase slightly due to increased crowding. Sewage sludge is shown to increase 10% in 1980 and 15% in 1990 due to three factors: (1) Extension of sewage systems to 100% of the population in metropolitan areas; (2) the introduction of tertiary treatment systems; (3) garbage disposers.

TABLE 101

CHANGES IN PER CAPITA MUNICIPAL WASTE GENERATION RATES

TYPE	1980	1980
Household	+22%	+49%
Street and Alley	+10%	+15%
Tree and Landscaping	-25%	-50%
Park and Beach	+ 5%	+10%
Catch Basin	+ 5%	+10%
Sewage Sludge	+10%	+15%

Table 102 is a list of coefficients for per capita generation of combustible wastes.

TABLE 102

COEFFICIENTS FOR PER CAPITA GENERATION OF COMBUSTIBLE WASTES
(pounds per person per day)

	Household and Other Munic.		Sewage Sludge	Total
	Organic	Synthetic	Organic	
1970	2.17	.08	.34	2.59
1980	2.49	.22	.37	3.08
1990	2.76	.63	.39	3.78

Although an attempt was made to determine the differential waste generation rates among SMSAs of different sizes, the results were inconclusive, and the generation rates listed in Table 102 were applied uniformly to all SMSAs.

The coefficients were applied to population projections for 242 Standard Metropolitan Statistical Areas, 25 Urban Zones, and 9 Major Regions of the country taken from *Dimensions of Metropolitanism* by Jerome P. Pickard, published by the Urban Land Institute. On the national level, Pickard's projection is compatible with the Census Series B for 1980 and falls midway between Series B and C for 1990. Table 103 lists these areas and their code numbers. Table 104 gives the results of applying the waste generation coefficients to these areas. Tables 103 and 104, because of their bulk, are not reproduced here, but may be viewed at the Solid Waste Division of the National Environmental Research Center.

COMMERCIAL AND INSTITUTIONAL WASTE GENERATION

In contrast to household and municipal solid waste generation, where figures developed by the 1968 National Survey of Community Solid Waste Practices were used, new waste generation coefficients for combustible solid waste from commercial (and institutional) sources were calculated. The reasons for this were twofold: (1) The data in the National Survey were developed from records kept by local governments. These records are much less complete and accurate for solid waste from commercial and institutional sources, much of which is collected and disposed of by private firms, than it is for household and municipal waste, which is handled by the municipality; and (2) Solid waste generation from commercial sources is not a function of population so much as of level of economic activity. Use of an average per capita generation factor introduces a potentially large error when applied to individual metropolitan areas which have varying amounts of commercial activity. Commercial wastes can be projected more accurately with coefficients that are related to the actual levels of commercial activity, such as employment or sales.

In developing these coefficients, estimates of waste generation published by the Incinerator Institute of America in *Incinerator Standards*, November 1968, were used.

SOLID WASTE FROM THE GENERAL OFFICE SECTOR

The General Office Sector does not, of course, correspond with any one or more SIC sectors, but represents office activities carried out within all sectors of the economy. These office functions are particularly important in the economies of metropolitan areas, which often serve as the "main offices" for large portions of the surrounding regions. Office activity will grow in importance as the United States economy continues to shift from manufacturing to service-oriented.

Essentially the same types of activities take place in offices whether those offices are a part of the insurance sector, the automobile manufacturing sector, the institutional sector, etc. Those activities are inter-office correspondence, intra-office correspondence, records-keeping, telephone communications, report writing, storage of reports, files, books, etc. Although different offices may give somewhat different emphases to these activities, the assumption was made that all offices have similar waste generation characteristics.

As a measure of office activity, the number of white collar employees was used. According to the Bureau of Labor Statistics, the white collar classification applies to professional and technical workers, managers, officials and proprietors, clerical workers, and sales workers. Since the Retail and Wholesale Sector is being considered separately, it was necessary to eliminate sales workers from consideration to avoid double counting. Sales workers were estimated to be about 15% of all white collar workers, based on Table 2 of *Occupational Manpower and Training Needs*, Bulletin 1701, Bureau of Labor Statistics.

The total number of white collar workers for 1980 and 1990 was obtained by using the Bureau of Labor Statistics 1980 projections and extrapolating to 1990. The percentage increases in white collar labor force were computed for the time intervals 1960-70, 1970-80, 1980-90. The most recent available data on the number of white collar workers in individual SMSA's was for 1960. The approximation was made that the number of white collar workers would increase at the same rate in every SMSA. The percentage increases derived from the national totals were then applied to the smsa figures to obtain the number of white-collar workers in each SMSA in 1970, 1980 and 1990.

In order to determine the solid waste generation rate of white collar workers, data was obtained from the Environmental Affairs Office of the General Services Administration indicating the average pounds per employee per day of solid waste generated by employees working in GSA-run office buildings. It was not known whether the approximately 1.9 pounds included cafeteria waste. An estimate of 1 pound per 100 square feet of office space per day was obtained from *Incinerator Standards*, published by the Incinerator Institute of America. From these two figures the average solid waste generated by white collar workers was estimated to be 1.7 pounds per day. Of this, 85% was estimated to be combustible, a higher percentage than for household waste, since offices do not consume as much of non-combustible materials such as glass and metals. Of this combustible amount, 97% is estimated to be natural materials, and 3% synthetic, approximately the same breakdown as for household waste.

In order to determine what the solid waste generation rate for white collar workers will be in the future, it is necessary to look at trends in the consumption and use of that material which makes up the greatest part of office waste: paper. A plot (Figure 31) of office-grade paper consumption against number of white collar employees reveals that between 1960 and 1970 paper consumption rose 75.8% while the number of white collar employees rose 37.4%. This probably represents a one-time phenomenon brought on by the rapid dissemination of Xerox and other city copying machines. The next generation in office technology, according to a proprietary marketing study done by a major corporation, will bring about a much more economical and efficient use of paper, particularly in data processing, and will strengthen the trend toward telecommunications and away from conventional mail. For example, (1) in the 1980's typewriters will be equipped with low cost display devices for document display prior to hard copy generation to eliminate intermediate draft copies; (2) microfilm systems and computer storage and retrieval systems will replace hard copy storage for information storage and retrieval; (3) computers will be equipped with visual display devices to enable selective hard copy output; and (4) conventional mail will drop in the 1980's from being the dominant mode of office-to-office communications to being one of several major modes including computer-to-computer, conventional telephone, visual display devices, and facsimile transmission. Behind these developments are the realization by business enterprises that paper systems will not be able to cope with burgeoning information-handling requirements, and the desire to decrease the amount of paper generated by business systems.

Figure 31 illustrates the projected rate of consumption of office-type paper, based on the above trends. When combined with the projections of number of white collar workers to get tons of paper consumed annually per white collar employee, this parameter decreases 5.5% from 1970 to 1980 and 24.2% from 1980 to 1990.

This rate of decrease was applied to the amount of combustible waste generated per white collar employee per day, giving 1.402 pounds per day in 1970, 1.325 pounds per day in 1980, and 1.004 pounds per day in 1990. The amount of synthetic combustible waste materials per white collar employee per day, .043 pounds, was held constant, as there are no visible trends affecting its generation.

Table 105 gives the solid waste generation coefficients for general office waste. These coefficients were applied to the number of white collar workers in each SMSA to give the daily tonnages of general office waste for 1970, 1980, and 1990. These figures are given in Table 106 which may be viewed at the Solid Waste Division of the National Environmental Research Center.

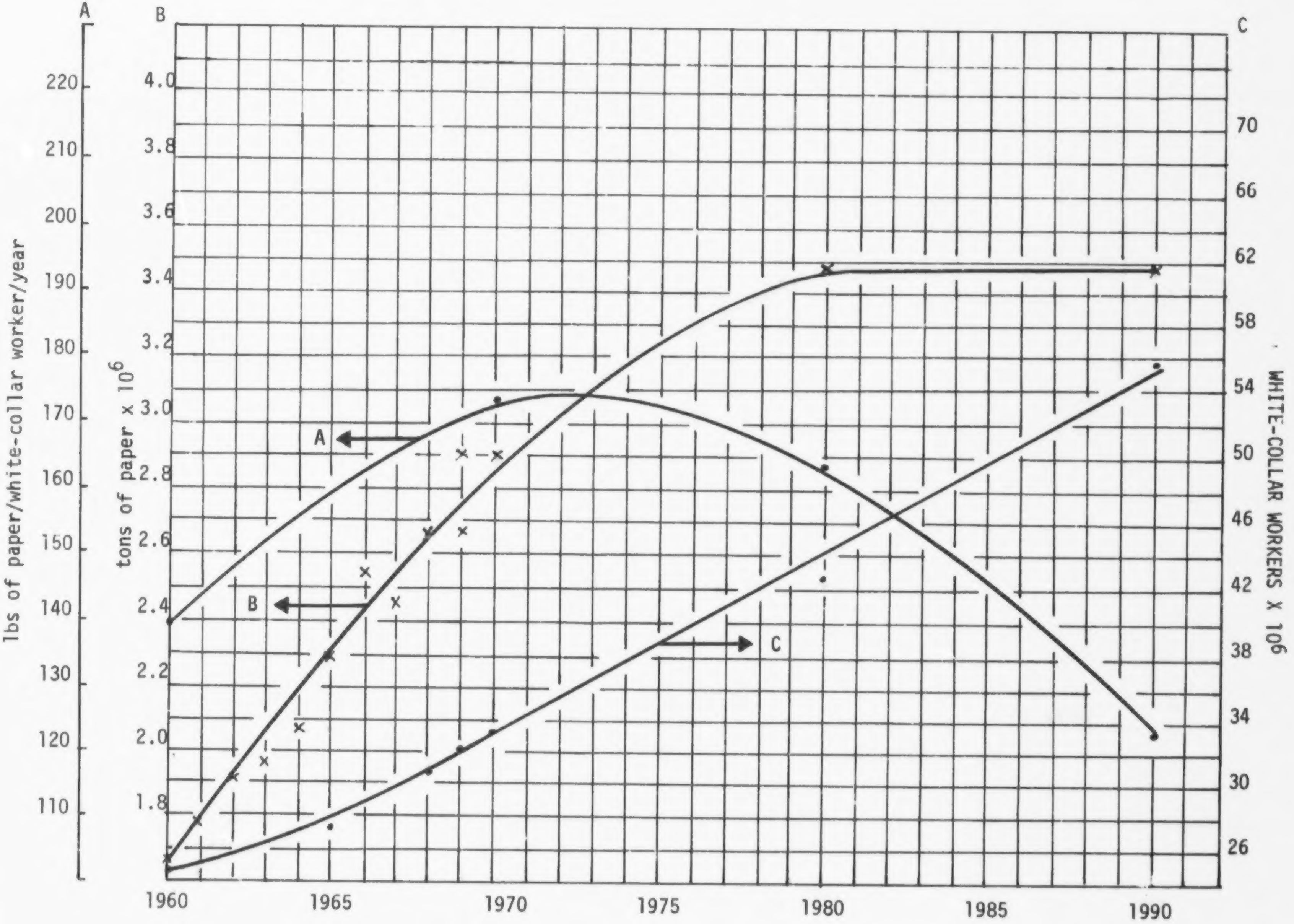

FIGURE 31: CONSUMPTION OF PAPER BY WHITE-COLLAR WORKERS

TABLE 105

SOLID WASTE GENERATION COEFFICIENTS FOR GENERAL OFFICE WASTE (pounds per white collar worker per day)

	Total Combustibles	Natural Materials	Synthetic Materials
1970	1.445	1.402	.043
1980	1.368	1.325	.043
1990	1.047	1.004	.043

SOLID WASTE FROM THE RETAIL AND WHOLESALE SECTOR

The second type of commercial activity that was analyzed for waste generation was wholesaling and retailing. This is also a function which is concentrated in metropolitan areas.

The solid waste generated by wholesaling and retailing is almost exclusively shipping waste and discarded packaging. Retailing generates considerably more waste than wholesaling, except where the wholesaler does extensive repackaging. The dominant material making up this waste is paperboard. Plastics are making an appearance in the form of filler material and plastic bags. The plastic bags, however, are generally carried away by the consumer and do not enter the waste stream in significant numbers.

Since shipping waste and packaging materials are a function of the number of items bought and sold by a firm, or the volume of business being done by that firm, it was decided to correlate waste generation with dollar volume of sales rather than with number of employees. The 1967 Census of Business provided a data base of wholesale and retail sales for each SMSA in 1967. Restaurant sales were deducted since restaurants are being treated separately. To project sales volumes for 1970, 1980, and 1990, economic projections done by Resources for the Future (RFF) with the Clopper Almon input-output model were used. Percentages increases between periods were derived and applied to the 1967 sales figures for individual SMSA's.

There exist no good published data on waste generation rates from wholesale and retail activities. However, the Incinerator Institute of America (IIA) estimates that the waste generation rate for warehousing is 2 pounds per 100 square feet per day. For retailing the estimates range from 4 pounds per 100 square feet per day for department stores to 9 pounds per 100 square feet per day for supermarkets. The IIA estimates are assumed to be somewhat high, since they are made for design purposes and must provide for maximum capacity. The combined waste generation rate for wholesale and retail activity was estimated at 3 pounds per 100 square feet of space per day. Using data on sales and commercial floor space from the Washington, D.C., Metropolitan Area, the average daily sales volume per 100 square feet was calculated to be $34, yielding a waste generation coefficient of 1 pound per $11.90 sales.

There are two trends visible regarding the waste generation characteristics of wholesaling and retailing. First, there is a trend developing for goods to be delivered from the wholesaler to the retailer in reusable cartons. Second, although the amount of plastic materials being used in shipping is still very small compared to the amount of paperboard, it is increasing. It was estimated that due to the first trend, the amount of combustible solid waste being generated per dollar of sales will decrease about 10% by 1980 and 20% by 1990. Due to the second trend, the amount of combustible synthetic waste per dollar of sales is expected to increase about 15% by 1980 and 30% by 1990. Table 107 gives the combustible solid waste generation coefficients for wholesale and retail establishments.

TABLE 107

COMBUSTIBLE SOLID WASTE GENERATION COEFFICIENTS
FOR WHOLESALE AND RETAIL ESTABLISHMENTS
(pounds per $11.90 of sales)

	Total Combustible	Natural Materials	Synthetic Materials
1970	1.00	.98	.02
1980	.903	.88	.023
1990	.818	.792	.026

Table 108, which may be viewed at the Solid Waste Division of the National Environmental Research Center, gives the results of applying these coefficients to sales volumes in the SMSA's.

SOLID WASTE FROM THE RESTAURANT SECTOR

Restaurants were analyzed as a separate economic sector for the following reasons: (1) they generate solid waste at a different rate than other commercial activities; (2) they generate a type of waste which is different from that generated by other commercial activities; and (3) restaurant sales are growing at a different rate than are other commercial activities.

The solid waste generated by restaurants is predominantly food scraps from both the preparation and consumption of meals. Additional amounts are contributed by discarded jars, bottles, cartons and other food wrappings. The Incinerator Institute of America estimates the waste generation rate at 2 pounds per meal. The estimate used was 1.5 pounds per meal. of this, about 78% is combustible solid waste, about the same proportion as for household waste. This percentage was projected to increase to 83% in 1980 and 90% in 1990. At the same time, the synthetic portion of the combustible amount was projected to increase from 4.3% in 1970 to 8.8% in 1980 and 19.3% in 1990. Both of these trends are due to the increasing substitution of plastic materials for glass and metal packaging. There are no visible trends which would affect the total amount of solid waste generated per meal in restaurants.

It was necessary to correlate the amount of waste per meal with the available data base of restaurant sales. This was done using data from the Washington, D.C. Metropolitan Area on restaurant sales and number of meals served. The coefficient was calculated to be 1.5 pounds of solid waste per $1.54 of restaurant sales.

Restaurant sales for each SMSA for 1967 were obtained from the 1967 Census of Business. Projections were made by constructing a time series of the percentage that total restaurant sales (from the Survey of Current Business) is of total GNP and projecting that percentage out to 1990. Actual total restaurant sales were than computed using GNP projections done by RFF using the Almon model. The rate of increase of restaurant sales was applied to the sales figures for individual SMSA's. Table 109 gives the waste generation coefficients for the restaurant sector. Application of these coefficients to retail sales in the SMSA's resulted in Table 110 which may be viewed at the Solid Waste Division of the National Environmental Research Center.

TABLE 109

WASTE GENERATION COEFFICIENTS FOR THE RESTAURANT SECTOR
(pounds per $1.54 of sales)

	Total Combustible	Natural Materials	Synthetic Materials
1970	1.17	1.12	.05
1980	1.25	1.14	.11
1990	1.35	1.09	.26

SOLID WASTE GENERATION FROM ELEMENTARY AND SECONDARY SCHOOLS

Primary and Secondary Education generates a significant amount of CSW. The solid wastes being considered here are only those from classroom activities, as those from office functions were included in the General Office Sector. Colleges and universities were excluded as their classroom wastes are considerably lower.

The Incinerator Institute of America estimates waste generation from elementary schools at 10 pounds per classroom and .5 pounds per pupil per day. High schools generate an estimated 8 pounds per classroom and .5 pounds per pupil per day. For reasons similar to those given above regarding IIA estimates, 75% of this 8-10 pounds per classroom rate seemed a more realistic average rate. It was estimated further that 90% of this solid waste was combustible. Using a conversion factor of 22.3 pupils per classroom obtained from the U.S. Office of Education, a combustible waste generation coefficient of .77 pounds per pupil per day is obtained for 1970. Of this amount, an estimated 97% is natural materials and 3% is synthetic. This is approximately the same breakdown as for general office waste.

Between 1970 and 1980 a 10% increase in the amount of paper waste generated per pupil was projected due to the increased use of copying machines in schools. Afte- 1980, however, increased reliance on electronic teaching aids is expected to lead to a slight decrease of about 15% in the use of paper in the classroom. There is no visible trend in the use of plastics in the classroom, so the amount of synthetic combustible waste was held constant. Table 111 gives the waste generation coefficients for elementary and secondary schools.

TABLE 111

WASTE GENERATION COEFFICIENTS FOR ELEMENTARY AND SECONDARY SCHOOLS (pounds per pupil per day)

	Total Combustible	Natural Materials	Synthetic Materials
1970	.77	.75	.02
1980	.85	.83	.02
1990	.72	.70	.02

The data base on which waste loads from schools were projected was school age population. School age was taken to be age five through age eighteen. Table 6 in the 1971 U.S. Statistical Abstract gives Bureau of the Census projections for these age groups. In 1970 they comprised 26.6% of the population; in 1980, using Series C, they will be 23.8%; in 1990, using Series D, they will be 22.8%. These percentages were applied to Pickard's population projections for standard metropolitan areas and regions to obtain the approximate number of school pupils in each area. Application of the generation coefficients to these area populations resulted in the data in Table 112 which may be viewed at the Solid Waste Division of the National Environmental Research Center.

SOLID WASTE GENERATION FROM HOSPITALS

Hospitals generate solid waste at a greater rate (on a pounds per patient per day basis) than any other activity under consideration. It is also likely to double or even triple in the foreseeable future. Although the amount of solid waste produced by hospitals varies markedly according to whether it is a teaching, research, mental or clinical hospital and according to the number of disposable items it uses, the average solid waste generation is estimated at 13 pounds per patient per day.[154,155,156] Of this amount, approximately 80% is combustible material.[157] By 1980, the combustible portion is expected to be about 83%, and by 1990, 90%. Of the combustible amount, the percentage that is synthetic materials is 4.2% for 1970, 8.8% for 1980, and 19.6% in 1990. These trends will be due to the increased use of disposable items of paper and plastic in place of items now made of glass and metal and fabric. Table 113 gives the solid waste generation coefficients for hospitals.

TABLE 113

SOLID WASTE GENERATION COEFFICIENTS FOR HOSPITALS
(pounds per patient per day)

	Total Combustible	Natural Combustible	Synthetic Combustible
1970	10.13	9.7	.43
1980	15.77	14.38	1.39
1990	22.50	18.10	4.40

Since it was not possible to collect data on the number of hospital beds in every SMSA, a percentage was applied to the population of each SMSA, representing the average proportion of the U.S. population that is hospitalized on any one day. This percentage was derived by constructing a time series from Table 98 of the 1971 U.S. Statistical Abstract, which gives the daily U.S. hospital census from 1950 through 1969. This series was plotted and projected to 1990. For 1970, this percentage is .65%, for 1980, .52%, and for 1990, .39%. The total hospital waste loads for each SMSA are given in Table 114 which may be viewed at the Solid Waste Division of the National Environmental Research Center.

APPENDIX C

PLANT TRASH

Plant trash generated in the manufacturing sectors, (SIC codes 19-39) has a high combustible component composed of containers, crates, packaging and wrapping materials, shipping pallets and dunnage which are discarded after use. In addition to packaging materials, plant trash contains all other production-generated wastes except process waste.

Most wooden containers, packing crates, and wooden barrels are reusable and are returned to the shipper or used economically in-house. The wood component of these plant trash figures is largely broken shipping containers, crates, and dunnage, although some wood and paper plant trash is generated internally as a result of maintenance, repair, and daily operation.

In spite of recycling corrugated and reusing shipping containers, almost all packing materials will eventually end up as waste, although the "inventory:waste" ratio will change.

As can be seen in Table 115, the composition of plant trash varies with each sector. Transportation Equipment (SIC 37) and Stone, Glass, and Clay Products (SIC 32) discard large quantities of shipping crates and dunnage, while the plant trash generated in Food and Kindred Products (SIC 20) contain a high proportion of paper, cartons, and corrugated.

The estimates of plant trash volumes were calculated on the basis of information contained in *Industrial Solid Waste Survey, 1970*, a report done by the Oregon State Board of Health. The report was based on on-site visits to several companies in each SIC manufacturing sector where estimates were obtained of the volume and composition of waste which was disposed of. Composition by volume was changed to composition by weight using waste-type density estimates which were also given in the report. For each SIC two digit code sector, total Oregon employment and total Oregon annual solid waste generation were also given.

From these data, waste generation per employee per year could be calculated for each type of waste for each sector. (There is no tobacco industry (SIC 21) in Oregon, and tobacco wastes were calculated from a report, *A Study of SWM in the Tobacco Products Industry*, U.S. Department of Health, Education, and Welfare, 1970.) Since these figures were total solid waste output, non-combustible material was ignored, and process waste representative of the sector was subtracted out (e.g., textile waste was eliminated from SIC Sector 22, Broadwoven Fabrics, and SIC 23, Apparel). The results are printed in Table 115. The administrative waste was subtracted

TABLE 115

PLANT TRASH GENERATION PER EMPLOYEE-YEAR

by SIC SECTOR, by TYPE OF WASTE
(1967)

Sector	Total Workers (000)		Production Workers (000)		lbs/employee/yr.*				Total Nationwide Waste for Entire Sector (lbs. x 1000)				
					Wood	Paper	Textile	Rubber & Plastic	Wood	Paper	Textile	Rubber & Plastic	Total
19	400.		215		113	300			45200	64500			129,700
20	1726.		1122						131210	1236097		31320	1,398,627
201	310.		249		163	1840			50530	458160			
202	232.		107		22	2080		135	5104	222560		31320	
203	260.		227		29	220			7540	4494			
204	112.	711	78	446	77	1196	0	34	54747	533416			
205	264.		160										
206	31.		25										
207	83.		69										
208	221		114										
209	137.		94		97	1805			13289	16967			
21	83.		66		116	52			18549	160517			179,066
22	954.		828		66	460			62964	38088			100,052
23	1373.		1200		55	1660		55	75515	1992000		75515	2,143,030
24	562.		496		386	620		55	216932	30752		30910	278,054
25	430.		358		342	590	126	35	147060	20768	54180	15050	232,058
26	671.		508		180	1060			120780	53848			174,628
27	1052.		632		82	480			86264	303360			389,624
28	983.		541		1200	910			1179600	492310			1,671,910
29	211.		99		750	3620			158250	358380			516,630
30	531.		410		1200	2150	73	73	637200	881500	38763	38763	1,596,226
31	337.		293		366	860	418	495	123342	251980	140866	166815	683,003
32	621.		469		1800	594			1117800	278586			1,396,386
33	1329.		1042		412	585			547548	609570			1,157,118
34	1375.		1057		1377	458			1893375	484106			2,377,481
35	1929.		1349		200	426			385800	574674			960,474
36	1981.		1324		27	710		27	53487	940040		53487	1,047,014
37	1936.		1337		1178	3390	47		2280608	4532430	90992		6,904,030
38	410.		266		80	450			32800	119700			152,500
39	423.		344		379	204	—	62	160317	70176		26226	256,719
	19323		13955						9465680	13336279	324795	438086	2,356,484
Average/production worker-year:					678-lbs.	956-lbs.	23-lbs.	31-lbs.					

* All employees,

Source: Industrial Solid Waste Survey, Oregon, 1970. Solid Waste Section, Oregon State Board of Health.

using the assumptions (i) paper waste generation rate was the same for production employees as it was for administrative employees, and (ii) administrative waste is entirely paper.

National SIC sector wastes by type were calculated by using Oregon's unit waste type generation rates and national SIC sector employment statistics for 1967 contained in the *Census of Manufactures*. Future trends and level of plant trash generation were projected on the basis of the two most important influences, (i) packaging materials trends, (ii) dollar output-level from the sector. Projections are tabulated in Table 116.

The results tabulated in Table 115 have some difficulties in addition to the assumptions and approximations already noted. No two companies generate or dispose of waste in exactly the same manner. Some are careful, recycle corrugated, reuse crates, salvage, give scrap wood to employees, or burn portions of their waste on-site and dispose of ashes. Some are not. It is difficult to explain the differences in waste levels given in the Oregon Report on the basis of the nature of the industrial activity alone.

The question of whether or not the characteristics of the Oregon Sector of the activity were representative of the industry nationwide was not investigated. Certainly this could be important, but to what degree is dependent on the industry.

In addition to these uncertainties, there were unavoidable errors introduced by the methods of estimation, approximation and sampling used. It is certain that sampling by volume and calculation of weight introduced a double error, where a single one could have been obtained at a higher cost (companies usually know volumes or bin loads, but not weights). Plastics were surely underestimated because of the method of the estimation -- 1% by volume was the smallest measured quantity, so that the smallest quantity (nationwide) which would appear in the report is about 20 M lbs.

On the other hand, comparison of materials inputs to wooden boxes and crate manufacturers, 1967, of 6.5 B lbs is not inconsistent with 9.5 B lbs of boxes, crates, dunnage and other wood wastes calculated on this basis. Longer-lifetime shipping containers result in a higher inventory-to-scrap ratio.

Considering the problems of waste reduction/disposal, the results are adequate. An increase or decrease of 25% in waste levels quoted here (a reasonable estimate of the error) would not affect the method of disposal, beyond a similar increase or decrease in landfill sites. Furthermore, although the composition of plant trash differs from that of municipal and commercial waste because of its higher wood content, it is almost as inhomogeneous and treatment is similar.

TABLE 116

PROJECTED PLANT TRASH WASTE LOADS 1980 and 1990

Sic Sector	Almon Sectors Included	Almon Sector Output Level (1967)(M$)	Almon Projected Output Level (1980)(M$)	Almon Projected Output Level (1990)(M$)	Growth 1980/1967	Growth 1990/1967	Projected Waste (1980)(M lbs.)	Projected Waste (1990)(M lbs.)
19	20-22	10,608	11,129	15,734	1.049	1.483	136.0	192.3
20	23-33	87,016	131.261	158,072	1.509	1.817	110.5	2,541.3
21	34	7,328	9,864	15,016	1.346	2.049	241.0	366.9
22	35-38	20,362	39,128	49,162	1.922	2.414	192.3	241.5
23	39-40	12,122	38,045	48,329	1.865	2.370	996.7	5,078.9
24	41-44	7,437	22,680	28,948	1.871	2,388	520.2	663.9
25	45-46	21,270	12,745	24,544	1.714	3.300	397.7	765.7
26	47-51	19.090	32,599	48,455	1.533	2.278	267.7	397.8
27	52-54	43,380	31,445	[illegible],501	1.647	2.384	641.7	928.8
28	55-68	23,353	72,669	101,287	1.676	2.335	2,802.1	3,903.7
29	69-71	12,746	[illegible],316	44,739	1.662	1.916	858.6	989.8
30	72-74	4,692	24.154	35,445	1.895	2.781	024.8	4,439.1
31	75-77	14,013	6,104	9,233	1.301	1.968	888.5	1,344.1
32	78-82	45,504	23,955	32,327	1.710	2.307	2,387.8	3,221.4
33	83-91	32,865	64,371	122,459	1.415	2.691	1,637.3	3,112.6
34	92-101	47,905	55,210	70,171	1.680	2.135	3,994.1	5,075.9
35	102-117	42,191	87,393	104,062	1.824	2.172	1,751.9	2,086.1
36	118-131	71,161	62,727	85,300	1.487	2.022	1,556.9	2,117.0
37	132-140	9,054	19,050	147,347	1.673	2.071	11,550.4	14,298.2
383	141-146	7,582	17,179	22,616	1.897	2.498	289.2	380.9
39	147-150	10,608	12,790	18.984	1.687	2.504	433.0	642.8
							39,697.2	52,789.8

Projected waste loads for 1980 and 1990, were calculated on the basis of the dollar output level growth in each sector, with a small shift in compostion away from wooden crates towards increased use of plastics, reflecting current trends in packaging. Table 116 summarizes the projection method and results.

Dollar output level projections for Almon economic sectors were available, equated with SIC sectors, and summed. The ratio of output levels 1980/1967 and 1990/1967, gave the growth of each SIC-defined sector, and total combustible plant wastes were assumed to grow in direct proportion to dollar output. Composition by weight of the combustible portion of plant trash and projected wasteloads are given in Table 117.

TABLE 117

COMPOSITION OF THE COMBUSTIBLE PORTION
OF PLANT TRASH

	1967		1980		1990	
	Amount B lb	% of Combustible	Amount B lb	% of Combustible	Amount B ib	% of Combustible
Wood	9.5	40.4	14.5	36.5	17.4	33.2
Paper	13.3	56.6	23.5	59.3	31.7	60.2
Textile	0.3	1.3	0.6	1.5	0.8	1.5
Rubber and Plastic	0.4	1.7	1.1	2.7	2.7	5.1
	23.5	100.0	39.7	100.0	52.8	100.0

APPENDIX D

REGIONAL DISTRIBUTION OF INDUSTRIAL PROCESS WASTE BY OBE AREA

Appendix D gives the regional distribution of combustible industrial process waste, for 1967 and projections for 1980 and 1990. The breakdown shows combustible waste as wood, paper, textile, rubber and plastic, and "other" components (solids content of waterborne waste). It includes waste generated in six SIC economic sectors which together account for more than 98% of the total combustible process waste generated nationwide in all industries. The geographical breakdown is by OBE areas. Table 118 (1967), 119 (1980), and 120 (1990) show industrial process waste, by type of waste, by OBE area.

METHOD

Combustible materials flows and combustible waste quantities in manufacturing sectors were both calculated for base year 1967 and projected to 1980 and 1990. A description of the methodology is given both in Chapter III and in Appendix A. The actual materials flows appear as Table 91 and Table 99.

Employment for each industry group (SIC two digit code) within each OBE area for 1966, and projections for 1980 and 1990 [done by the Regional Economics Division of the Office of Business Economics], were used to allocate base year and future industrial CSW among 173 OBE areas. The assumption was made that, for each SIC sector, wasteloads, calculated above, were distributed among OBE areas in direct proportion to the fraction of total U.S. employees within an economic sector who were employed within each OBE area. The percentage of employees, nationwide, in a given SIC economic sector who are employed in that economic sector in each OBE area was calculated, e.g., if Bangor Maine (OBE 001) was expected to employ 1.15% of the total U.S. employment in SIC sector 26 in 1980 (Pulp, Paper and Allied Industries), that OBE area would be assigned 1.15% of the projected SIC 26 (= Almon Sectors 47-51) wasteload for 1980).

Although the method was straightforward and rather detailed geographically, the assumption that waste parallels employment is often subject to some qualification:

(1) Regional variances in waste disposal practices, and local ordinances restricting burning, or dumping, would cause the true "waste generation rate per employee" to change from area to area.

(2) Plant size and associated economies of scale affect waste generation rates both because of a different materials throughput per employee, and because large plants tend to produce more marketable

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quantities of residuals. True "waste generation per employee" would tend to be lower in a small operation in the first case, higher in the second case, and so would tend to cancel each other.

(3) The industry associated with each SIC sector includes many different sub-industries each of which has many waste generating unit processes. Some regions might be dominated by a high-waste generating subsector and othersby low waste generating subsectors, e.g. pulp mills and paper mills are both in SIC sector 26 but have very different waste/employee. Similarly, the age of the included plant machinery would be important. The same function performed by a different generation machine would generate different amounts of waste. Generally, the regional distribution of all manufacturing processes within an SIC sector is not uniform nationwide.

Since employment projections were available by SIC economic sectors, and the industrial CSW projections were done on the basis of Almon sectors, the Almon-SIC code cross index was used to determine projected SIC sector waste loads. The E-LO projected wasteloads in Table 99 were used. Furthermore, the aggregation of specific material flows so that projections could be made (i.e. the difference between Table 91 and 99; Base Year) made it possible to determine the exact composition of projected waste generated in 1980 and 1990. The approximation was made that the composition in those years would be the same as in 1967 (base year).

TABLE 118

Industrial Process Waste - 1967
(by OBE Area, by Waste Type; M lb.)

OBE AREA	PAPER	WOOD	RUBBER & PLASTIC	TEXTILE	OTHER
001 Bangor, Maine	8.86	146.45	1.72	.28	229.59
002 Portland, Me.	14.96	271.28	2.84	1.66	368.08
003 Burlington, Vt.	6.45	190.99	1.04	0.03	130.46
004 Boston, Mass.	62.12	610.60	6.35	5.54	828.08
005 Hartford	35.42	242.33	4.89	11.92	14.28
006 Albany-Troy-Schnectdy, NY	19.22	146.63	2.87	.62	390.79
007 Syracuse,NY	14.27	109.11	2.05	6.12	273.22
008 Rochester, NY	9.76	64.05	.86	.82	117.27
009 Buffalo, NY	17.10	318.12	2.03	5.65	230.70
010 Erie, Pa.	3.39	86.72	0.52	1.46	57.38
011 Williamsport, Pa.	4.60	118.19	.81	.90	99.25
012 Binginhapton, NY	4.55	99.14	.31	.96	32.49
013 Wilkes Barre-Hazelton, Pa	5.40	92.77	.30	0.94	33.91
014 New York	196.06	1240.23	14.13	16.65	1850.33
015 Phila, Pa.	74.38	447.82	7.42	10.09	978.55
016 Harrisburg, Pa.	17.62	369.71	2.09	1.48	271.54
017 Baltimore, Md.	19.52	257.36	1.79	5.16	233.55
018 Washington, DC-Va. - Md.	22.20	86.05	.24	.36	30.56
019 Stanghton, Va.	2.01	149.60	.23	.24	22.57
020 Roanoke, Va.	7.72	671.56	1.43	.91	148.87
021 Richmond, Va.	10.20	388.34	1.53	.63	187.12
022 Norfolk-Portmouth, Va.	5.33	180.58	1.08	4.24	67.39
023 Raleigh, NC.	6.84	417.03	1.03	.75	117.13
024 Wilmington, NC.	1.73	111.45	.29	.26	30.59
025 High Point, NC. Greensboro-Winston-Salem	6.34	897.65	1.10	1.43	84.74
026 Charlotte, NC.	9.35	1091.83	1.66	1.76	147.50
027 Ashville, SC.	6.11	184.64	1.21	.32	154.39
028 Greenville, SC.	2.86	95.53	.46	.22	58.09
029 Columbia, SC.	1.93	229.17	0.25	.35	19.59
030 Florence, SC.	5.38	140.03	1.08	.19	140.87
031 Charleston, SC.	3.29	93.03	.65	1.36	75.93
032 Augusta, Ga.	3.00	149.61	.09	.26	63.73
033 Savannah, Ga.	7.25	162.46	1.43	.48	186.67
034 Jacksonville, Fla.	12.77	200.98	2.07	1.08	271.68
035 Orlando, Fla.	3.34	76.55	.14	.42	15.62
036 Miami, Fla.	9.27	128.54	.58	2.43	58.38
037 Tampa-St. Petersburg	6.46	92.58	.33	.66	47.00
038 Tallahasse, Fla.	3.91	12.76	.73	.22	93.39
039 Pensacola, Fla.	3.34	70.05	.58	.15	75.58
040 Montgomery, Fla.	1.92	270.52	.20	.37	10.84
041 Albany, Ga.	2.04	165.62	.33	.44	34.41
042 Macon, Ga.	2.85	210.16	.53	.46	58.58
043 Columbus, Ga.- Ala	1.47	127.36	.09	.29	5.11

Table 118 (con't)

OBE AREA	PAPER	WOOD	RUBBER & PLASTIC	TEXTILE	OTHER
044 Atlanta, Ga.	17.06	432.21	2.27	4.98	263.57
045 Birmingham, Ga.	9.83	636.91	1.47	1.52	156.82
046 Memphis, Tenn.-Ark.	9.32	506.38	1.14	1.27	120.82
047 Huntsville, Ala.	2.16	95.60	.28	.38	31.90
048 Charttanooga, Tenn.-Tenn.	4.42	232.44		.49	82.62
049 Nashville, Tenn.	7.89	322.19	.38	1.72	24.68
050 Knoxville	2.73	432.92	.40	.70	5.40
051 Bristol, Va.-Tenn.	4.92	163.34	.46	.27	53.04
052 Huntington	2.87	207.06	.19	.60	10.73
053 Lexington, Ky.	2.37	95.54	.14	.25	14.68
054 Louisville, Ky.-Ind.	3.49	286.84	.73	1.12	18.61
055 Evansville, Ind.	3.39	353.38	.47	.64	59.55
056 Terre Haute, Ind.	2.47	15.96	.22	.11	30.83
057 Springfield, Ill.	3.28	25.57	.19	.24	27.46
058 Champaign-Urbana, Ill.	2.28	12.76	.05	.09	8.34
059 Lafayette West-Lafayette, Ind.	2.46	63.77	.09	.30	6.69
060 Indianapolis, Ind.	12.87	177.68	1.38	4.76	155.27
061 Muncie, Ind.	4.73	71.36	.60	2.38	64.20
062 Cincinnati, Ohio-Ky., Ind.	23.31	224.78	2.87	3.77	369.67
063 Dayton, Ohio	15.93	68.14	1.30	2.31	162.97
064 Columbus, Ohio	13.28	128.17	1.55	1.69	203.60
065 Clarkesburg, W. Va.	1.12	54.10	.11	.08	12.31
066 Youngstown, Warren, Ohio	17.21	211.25	1.59	2.40	206.62
067 Cleveland,Ohio	2.37	82.53	.67	10.55	3.41
068 UMA, Ohio	1.81	32.53	.22	1.24	21.15
069 Toledo, Ohio	8.21	97.20	1.12	3.09	131.98
070 Detroit, Mich.	27.60	186.20	3.81	46.27	200.14
071 Saginaw, Mich.	2.59	157.44	.32	2.75	16.48
072 Grand Rapids, Mich.	9.12	411.88	1.35	2.79	143.70
073 Lansing, Mich	15.06	120.17	2.50	4.29	317.82
074 Fort Wayne, Ind.	4.87	93.37	1.38	1.97	52.22
075 South Bend, Ind.	9.23	243.34	1.48	2.81	172.54
076 Chicago, Ill.	103.88	939.39	8.40	7.85	1107.09
077 Peoria, Ill.	3.75	25.51	.23	.15	37.49
078 Davenport, Iowa Moline, Iowa Rock Island, Ill.	4.62	83.81	.49	.24	64.65
079 Cedar Rapids, Iowa	2.79	9.55	.17	.04	27.34
080 Dubuque, Iowa	1.48	44.61	.08	.16	11.44

Table 118 (con't)

OBE AREA	PAPER	WOOD	RUBBER & PLASTIC	TEXTILE	OTHER
081 Rockford, Ill.	3.77	73.95	.23	1.38	21.25
082 Madison, Wisc.	2.33	44.61	.08	.17	12.86
083 Milwaukee, Wisc.	21.84	168.06	1.74	4.68	214.01
084 Green Bay, Wisc.	26.30	337.75	4.71	1.12	630.70
085 Wausau, Wisc	12.31	162.37	2.33	.37	312.96
086 Duluth, Minn. Superior, Wisc.	7.97	95.54	1.33	.24	178.30
087 Eau Claire, Wisc.	3.01	54.13	.47	.14	63.84
088 LaCrosse, Wisc.	1.21	44.61	.08	.16	10.14
089 Rochester, Minn.	1.24	22.28	.06	.06	13.45
090 Minneapolis, Minn. St. Paul, Minn.	27.92	216.92	2.22	1.26	309.05
091 Grand Forks, N.D.	.55	9.55	.01	.02	1.78
092 Minot, N.D.	.28	3.18	0	0	.47
093 Great Falls, Mont.	.73	19.10	.01	.03	.95
094 Billings, Mont.	.83	15.91	.02	.03	3.21
095 Bismarck, N.D.	.28	0	0	0	.47
096 Fargo, N.D. Moorhead, Minn.	.94	9.58	.02	.07	2.57
097 Aberdeen, S.D.	.38	3.18	0	0	.71
098 Sioux Falls, S.D.	1.42	3.18	.01	.03	7.36
099 Rapid City, S.D.	.64	25.49	.01	.09	.83
100 Scotts Bluff, Nebr.	.32	3.18	0	.01	.95
101 Grand Island, Nebr.	1.12	3.23	.03	.09	5.96
102 Sioux City, Iowa Sioux City, Nebr.	1.64	3.23	.01	.11	7.12
103 Fort Dodge, Iowa	1.21	9.55	.01	.03	3.79
104 Waterloo, Iowa	.72	6.42	.05	.12	12.98
105 Des Moines, Iowa	5.57	31.89	.28	.19	41.07
106 Omaha, Nebr Iowa	4.92	35.10	.22	.27	36.48
107 Lincoln, Nebr.	1.97	25.52	.02	.16	3.20
108 Salinas, Kansas	.85	3.23	0	.09	1.42
109 Wichita, Kansas	3.31	30.95	.33	4.00	18.37
110 Kansas City, Mo. Kansas	19.43	106.32	1.32	2.42	177.76
111 Columbia, Mo.	1.92	12.75	.02	.06	2.69
112 Quincy, Ill.	2.84	38.22	.34	.11	46.02
113 St. Louis, Mo. Ill.	22.98	259.34	2.31	8.51	263.01
114 Paducah, Kentucky	1.09	9.69	.03	.27	4.40
115 Springfield, Mo.	5.45	191.18	.55	.64	64.77
116 Little Rock, Ark.	5.54	372.58	.86	.88	92.03
117 Fort Smith, Okla.	2.06	194.16	.32	.29	31.54
118 Tulsa, Okla.	4.39	48.07	.21	.66	29.10
119 Okla.City, Okla.	4.04	48.10	.11	.70	13.10
120 Wichita Falls, Tex.	.79	19.15	.01	.11	7.66

Table 118 (Con't)

OBE AREA	PAPER	WOOD	RUBBER & PLASTIC	TEXTILE	OTHER
121 Amarillo, Texas	1.29	12.74	.01	.05	1.89
122 Lubbock, Texas	1.40	9.55	.15	.02	21.03
123 Odessa, Texas	.60	6.37	.01	.01	2.50
124 Abilene, Texas	1.01	0.03	.16	.06	24.50
125 San Angelo, Texas	.52	9.56	0	.04	.47
126 Dallas, Texas	20.24	200.92	1.96	6.47	225.68
127 Waco, Texas	1.23	73.31	.09	.28	7.40
128 Austin, Texas	1.91	50.95	.32	.12	42.32
129 Tyler, Texas	2.68	270.61	.44	.52	41.70
130 Texarkana, Tex.	1.52	210.07	.28	.31	25.80
131 Shreveport, La.	2.62	206.90	.63	.32	72.46
132 Monroe, La.	7.07	213.31	1.43	.41	181.40
133 Greenville, Miss.	4.43	337.41	.94	.51	105.22
134 Jackson, Miss.	2.58	232.42	.42	.37	42.18
135 Meridian, Miss.	5.73	388.30	1.28	.53	150.43
136 Mobile, Ala.	10.81	258.64	2.19	1.79	276.72
137 New Orleans, La.	13.10	242.78	1.97	1.91	256.29
138 Lake Charles, La.	2.16	63.82	.25	.39	30.46
139 Beaumont, Texas Port Arthur Orange	2.75	130.72	.50	.57	56.44
140 Houston, Texas	9.97	165.89	.97	.93	110.42
141 San Antonio, Texas	3.57	48.14	.15	.79	18.35
142 Corpus Christi, Tex.	.97	9.60	.01	.10	1.89
143 Brownsville, Texas Harlingen San Benito	.48	3.20	.01	.05	5.82
144 El Paso, Texas	2.14	16.02	.02	.22	2.37
145 Albuquerque, N.M.	1.50	44.57	.03	.10	1.54
146 Pueblo, Colo.	1.56	9.63	.03	.15	3.33
147 Denver, Colo	8.13	62.42	.49	3.47	47.86
148 Grand Junction,Colo.	.55	19.10	.08	.02	10.18
149 Cheyenne, Wyo.	.70	12.75	.01	.05	.59
150 Salt Lake City,Utah	4.14	45.21	.19	1.20	18.61
151 Idaho Falls, Idaho	1.12	15.93	.02	.09	7.59
152 Butte, Mont.	.64	203.69	.17	.26	8.24
153 Spokane, Wash.	4.25	369.24	.65	.59	62.99
154 Seattle, Washington Everett, Washington	21.17	1053.03	3.71	11.54	268.13
155 Yakima, Wash.	1.50	171.89	.28	.29	28.55
156 Portland, Ore.	18.62	1172.30	3.51	3.40	388.72
157 Eugene, Ore.	2.37	1190.34	.82	1.59	19.00
158 Boise City, Idaho	1.01	111.50	.09	.34	5.35
159 Reno, Nevada	.66	15.91	.12	.02	15.78
160 Las Vegas, Nevada	.70	22.28	.01	.03	.59
161 Phoenix, Arizona	5.38	89.71	.37	1.16	42.06
162 Tucson, Arizona	1.99	25.47	.22	.07	29.77
163 San Diego, Calif.	4.34	35.89	.23	3.25	8.82
164 Los Angeles, Calif. Long Beach	58.91	1019.48	5.04	13.40	578.64

Table 118 (con't)

OBE AREA	PAPER	WOOD	RUBBER & PLASTIC	TEXTILE	OTHER
165 Fresno, Calif.	3.09	79.65	.11	.28	15.23
166 Stockton, Calif.	3.51	108.30	.40	.37	55.49
167 Sacramento, Calif.	5.66	133.73	.34	.33	42.14
168 Redding, Calif.	1.31	257.79	.33	.32	25.35
169 Eureka, Calif.	.69	308.71	.26	.39	12.07
170 San Fran-Oakland, Calif.	37.38	378.54	3.25	5.78	416.82
171 Anchorage, Alaska	3.12	44.58	.55	.10	73.79
172 Honolulu, Hawaii	3.82	32.17	.16	.69	25.36

TABLE 119

Industrial Process Waste - 1980

(by OBE Area, by Waste Type, M lb)

OBE AREA		PAPER	WOOD	RUBBER & PLASTIC	TEXTILE	OTHER
001	Bangor, Me.	13.68	254.82	2.69	.48	363.73
002	Portland, Me.	22.05	403.55	4.12	2.42	541.60
003	Burlington, Vt.	9.62	285.35	1.50	.51	190.33
004	Boston, Mass.	97.43	905.46	9.69	7.78	1,291.02
005	Hartford, Conn.	59.71	409.02	7.79	20.41	934.25
006		28.58	260.16	4.30	1.01	591.33
007	Syracuse, N.Y.	21.31	164.53	2.90	2.84	387.91
008	Rochester, N.Y.	15.95	102.73	1.40	1.64	190.11
009	Buffalo, N.Y.	25.91	499.05	3.01	9.07	339.52
010	Erie, Pa.	5.26	144.12	.27	2.72	87.03
011	Williamsport, Pa.	7.20	189.25	1.24	1.56	152.06
012	Binghampton, N.Y., Pa.	7.44	158.80	.50	1.74	52.93
013	Wilkes-Barre, Hazelton, Pa.	8.86	163.73	.53	1.47	60.92
014	New York, N.Y.	303.89	1,891.44	21.32	23.19	2,846.72
015	Philadelphia, Pa.	116.92	716.10	11.47	14.93	1,534.00
016	Harrisburg, Pa.	28.16	627.58	3.43	2.65	447.31
017	Baltimore, Md.	33.49	391.42	2.98	7.98	390.73
018	Washington, D.C.	34.50	142.82	.48	.57	63.69
019	Stanton, Va.	3.56	244.58	.38	.43	40.31
020	Roanoke, Va.	13.10	1,161.55	2.47	1.62	257.74
021	Richmond, Va.	16.73	596.12	2.52	1.01	313.11
022	Norfolk - Portsmouth, Pa.	111.74	3,163.66	8.86	10.83	1,106.10
023	Raleigh, N.C.	11.27	626.78	1.72	1.19	198.65
024		1.75	178.42	.45	.44	47.36
025	Greensboro-Winston-Salem, High Point	10.49	1,518.36	1.86	2.43	143.86
026	Charlotte, N.C.	16.39	1,824.08	2.95	2.98	273.77
027	Ashville, S.C.	9.21	300.67	1.84	.59	235.14
028	Greenville, S.C.	3.27	163.11	.81	.39	103.76
029	Columbia, S.C.	3.25	356.66	.44	.59	34.82
030	Florence, S.C.	9.79	208.89	1.02	0.31	129.13
031	Charleston, S.C.	5.24	133.55	1.04	2.05	123.12
032	Augusta, Ga.	4.94	249.69	.93	.45	112.27
033	Savannah, Ga.	10.78	244.83	2.15	.87	284.70
034	Jacksonville, Fla.	21.79	301.45	3.57	1.94	476.42
035	Orlando, Fla.	7.13	112.45	.25	.85	27.75
036	Miami, Fla.	16.06	323.38	.99	4.67	100.36
037	Tampa, St. Petersburg, Fla.	12.11	148.23	.56	1.19	82.38
038	Tallahassee, Fla.	6.26	193.63	1.14	.34	148.28
039	Pensacola, Fla.	4.88	96.89	.86	.29	113.33
040	Montgomery, Fla.	4.31	428.39	.64	1.40	57.03
041	Albany, Ga.	4.09	254.95	.74	.77	87.10

TABLE 119 - con't

OBE AREA	PAPER	WOOD	RUBBER & PLASTIC	TEXTILE	OTHER
042 Macon, Ga.	4.00	321.12	.94	.75	104.86
043 Columbus, Ga. Ala	2.53	193.72	.21	.51	16.97
044 Atlanta, Ga.	30.72	636.05	3.99	8.35	472.54
045 Birmingham, Ga.	15.24	1065.39	2.55	2.62	274.18
046 Memphis, Tenn. Ark.	15.70	826.30	3.01	1.91	223.17
047 Huntsville, Ala.	3.76	137.78	.45	.62	55.24
048 Chattanooga, Tenn.	7.07	321.12	1.05	.76	124.18
049 Nashville, Tenn.	11.78	561.66	.72	2.97	49.74
050 Knoxville, Tenn.	4.75	723.50	.70	1.16	45.39
051 Bristol, Va. Tenn.	8.33	249.67	.79	.43	95.43
052 Huntington-Ashland W. Va., Ky.,Ohio	4.51	305.94	.34	.90	23.39
053 Lexington, Ky.	3.96	137.64	.24	.36	26.69
054 Louisville, Ky.-Ind.	14.36	469.34	1.30	1.85	151.98
055 Evansville, Ind.	5.68	606.38	.81	1.09	69.64
056 Terre Haute, Ind.	2.84	25.54	.38	.17	52.87
057 Springfield, Ill.	5.19	46.02	.33	.39	47.71
058 Champaign-Urbana, Ill.	3.34	20.45	.06	.18	10.16
059 Lafayette,West Lafayette, Ind.	4.07	107.17	.12	.46	7.79
060 Indianopolis, Ind.	21.46	268.36	2.19	7.93	249.07
061 Muncie, Ind.	7.33	108.35	.84	2.47	98.14
062 Cincinnati, Ohio/ Ky./Ind.	35.20	379.85	4.21	5.49	548.12
063 Dayton, Ohio	25.11	103.92	2.11	3.63	271.55
064 Columbus, Ohio	21.71	190.05	2.44	2.97	321.96
065 Clarkesburg, W.Va.	1.83	91.70	.18	.13	20.03
066 Pittsburgh	27.64	359.98	2.72	4.68	369.37
067 Youngstown, Warren, Ohio	3.71	123.99	.37	3.09	25.30
068 Cleveland, Ohio	62.90	432.18	5.93	16.54	710.09
069 UMA, Ohio	3.05	62.31	.38	2.09	37.54
070 Toledo, Ohio	13.17	257.25	1.73	4.69	198.38
071 Detroit, Mich.	45.65	311.11	5.32	61.50	305.82
072 Saginaw, Mich.	5.03	256.99	.64	4.22	45.73
073 Grand Rapids, Mich.	14.89	679.59	2.09	4.41	221.71
074 Lansing, Mich.	22.84	207.23	3.65	6.19	466.38
075 Fort Wayne, Ind.	7.74	124.08	.76	3.29	82.47
076 South Bend, Ind.	14.56	414.84	2.28	4.31	267.85
077 Chicago, Ill.	162.48	22.17	14.36	13.67	1829.08
078 Peoria, Ill.	5.40	56.09	.33	.22	51.67
079 Davenport-Rock Island Moline, Iowa	7.29	142.76	.78	.44	105.79
080 Cedar Rapids, Iowa	4.63	15.28	.30	.07	47.31
081 Dubuqu, Iowa	2.34	61.20	.14	.25	19.15
082 Rockford, Ill.	5.84	133.75	.42	2.40	37.20
083 Madison, Wisc.	3.89	76.48	.16	.32	28.26
084 Milwaukee, Wisc.	35.96	262.64	4.19	7.02	547.65
085 Green Bay, Wisc.	40.85	510.05	7.45	1.78	1011.68

Table 119 - con't

OBE AREA	PAPER	WOOD	RUBBER & PLASTIC	TEXTILE	OTHER
086 Wausau, Wisc.	19.11	254.85	3.66	.59	498.25
087 Duluth Superior Minn., Wisc.	12.51	147.83	2.10	.37	286.42
088 Eau Claire, Wisc.	4.71	76.46	.73	.23	100.45
089 LaCrosse, Wisc.	2.10	71.42	.14	.28	16.48
090 Rochesterm Minn.	2.27	40.75	.16	.12	28.54
091 Minneapolis-St. Paul	48.85	342.15	4.05	2.12	572.34
092 Grand Forks, Na.	.55	15.28	.01	.03	1.78
093 Minot.Na.	.22	5.09	0	.01	.59
094 Great Falls, Mont.	.90	30.57	.02	.05	1.19
095 Billings, Mont.	1.16	30.57	.04	.05	4.50
096 Bismarck, N.D.	.47	0	0	.01	.79
097 Fargo, Moorhead, N.D. Minn.	1.51	15.33	.03	.12	5.49
098 Aberdeen, S.D.	.50	5.09	0	.02	1.19
099 Sioux Falls, S.D.	2.12	5.11	.03	.11	12.81
100 Rapid City, S.D.	.75	35.69	.02	.14	.99
101 Scotts Bluff, Nebr.	.48	.02	0	.05	.99
102 Grand Forks, Nebr.	1.23	5.16	.05	.14	7.25
103 Sioux City Iowa-Nebr.	1.01	5.16	.04	.19	12.02
104 Fort Dodge, Iowa	1.68	10.21	.01	.11	7.33
105 Waterloo, Iowa	3.28	10.26	.15	.20	24.44
106 Des Moines, Iowa	8.82	56.16	.49	.33	72.02
107 Omaha, Nebr.-Iowa	7.82	71.49	.35	.50	59.98
108 Lincoln, Nebr.	2.90	45.97	.04	.30	5.94
109 Salsna, Kansas	.53	5.16	.03	.14	5.13
110 Wichita, Kan.	4.28	54.56	.37	6.24	10.28
111 Kansas City, Mo.-Kan.	32.30	165.19	2.04	4.06	271.13
112 Columbia, Mo.	2.89	25.49	.04	.09	6.08
113 Quincy, Ill.	4.56	71.37	.57	.19	77.92
114 St. Louis, Mo.-Ill.	35.99	320.40	3.63	14.79	406.99
115 Paducah, Ky.	1.71	158.11	.15	.54	9.77
116 Springfield, Mo.	8.71	316.27	.92	1.19	105.20
117 Little Rock-No Little Rock, Ark.	9.05	560.74	1.44	1.40	159.92
118 Fort Smith, Okla.	3.03	320.95	.45	.47	42.42
119 Tulsa, Okla.	7.52	72.06	.38	1.43	49.74
120 Okla City, Okla.	6.61	71.85	.21	1.28	24.44
121 Wichita Falls, Tex.	.97	30.64	.03	.17	1.98
122 Amarillo, Tex.	1.55	20.40	.01	.08	2.57
123 Lubbock, Tex.	.80	15.28	.01	.03	1.58
124 Odessa, Tex.	.85	5.09	.02	.02	3.90
125 Abilene, Tex.	1.51	.05	0	.09	2.18
126 San Angelo, Tex.	.74	15.30	.01	.07	.79
127 Dallas, Tex.	34.70	347.07	3.21	10.25	378.72

Table 119 - con't

OBE AREA	PAPER	WOOD	RUBBER & PLASTIC	TEXTILE	OTHER
128 Waco, Tex.	2.11	127.55	.19	.50	14.99
129 Austin, Tex.	3.25	91.75	.05	.22	3.76
130 Tyler, Tex.	4.68	443.39	.76	.92	74.08
131 Texarkana, Tex.	3.01	321.00	.55	.55	54.25
132 Shreveport, La.	5.52	341.37	.99	.53	114.59
133 Monroe, La.	10.86	321.07	2.22	.65	287.75
134 Greenville, Miss.	6.31	570.62	1.45	.86	157.69
135 Jackson, Miss.	4.37	387.33	.75	.82	78.57
136 Mekidian, Miss.	9.13	662.27	2.06	.89	239.24
137 Mobile, Ala.	19.05	403.66	3.85	2.62	499.24
138 New Orleans, La.	21.32	363.30	3.22	3.31	424.80
139 Lake Charles, La.	3.48	97.08	.44	.65	55.05
140 Beaumont-Port Arthur, Orange, Tex.	4.24	193.92	.71	.82	82.54
141 Houston, Tex.	17.27	270.65	1.46	1.54	189.79
142 San Antonio, Texas	6.13	77.08	.25	1.32	30.12
143 Corpus Cristi, Texas	1.43	15.38	.02	.20	2.77
144 Brownsville, Harlingen, San Benito, Texas	1.27	5.11	.04	.09	12.55
145 El Paso, Texas	3.25	25.64	.03	.34	3.76
146 Albuquerque, New Mexico	2.49	71.34	.04	.15	2.57
147 Pueblo, Colorado	2.58	15.40	.04	.24	5.49
148 Denver, Colorado	14.32	112.79	.60	1.47	82.26
149 Grand Junction, Colorado	.74	40.75	.13	.06	16.52
150 Cheyenne, Wyoming	1.01	25.69	.02	.08	.99
151 Salt Lake City, Utah	6.94	77.42	.30	1.87	30.45
152 Idaho Falls, Idaho	1.92	30.59	.05	.15	13.60
153 Butte, Montana	1.52	376.99	.35	.52	19.63
154 Spokane, Washington	6.45	560.46	1.07	.89	107.45
155 Seattle - Everett, Washington	34.08	1,611.16	5.97	19.73	597.56
156 Yakima, Washington	2.44	300.61	.47	.50	46.72
157 Portland, Oregon	31.21	1,764.39	5.72	5.37	653.19
158 Eugene, Oregon	4.27	1,833.98	1.40	2.44	46.47
159 Boise City, Idaho	1.54	193.75	.14	.56	9.04
160 Reno, Nevada	1.28	20.38	.01	.03	.99
161 Las Vegas, Nevada	1.43	35.66	.02	.05	1.19
162 Phoenix, Arizona	9.42	128.51	.60	2.16	66.15
163 Tucson, Arizona	3.04	45.90	.29	.15	39.25
164 San Diego, Calif.	7.60	69.32	.38	5.36	15.06
165 Los Angeles - Long Beach, Calif.	109.62	1,549.88	9.43	39.11	1,016.53
166 Fresno, Calif.	5.55	137.68	.21	.50	29.19

Table 119 - con't

OBE AREA		PAPER	WOOD	RUBBER & PLASTIC	TEXTILE	OTHER
167	Stockton, Calif.	7.34	188.63	.66	.63	96.73
168	Sacramento, Calif.	9.99	203.91	.54	.59	69.57
169	Redding, Calif.	2.57	346.41	.55	.45	50.49
170	Eureka, Calif.	1.12	463.57	.40	.59	19.63
171	San Francisco - Oakland, Calif.	62.69	564.75	4.86	8.53	642.00
172	Anchorage, Alaska	5.07	137.56	.94	.22	122.72
173	Honolulu, Hawaii	6.48	56.57	.27	1.10	45.84

TABLE 120
Industrial Process Waste - 1990
(by OBE Area, by Waste type; M lb)

OBE AREA	PAPER	WOOD	RUBBER & PLASTIC	TEXTILE	OTHER
001 Bangor, Maine	17.83	329.88	3.48	.57	494.37
002 Portland, Maine	28.59	505.77	5.26	2.96	724.94
003 Burlington, Vt.	12.81	349.30	1.89	.63	252.10
004 Boston, Mass.	131.48	1,110.35	12.64	9.43	1,766.40
005 Hartford, Conn.	84.20	533.55	10.36	28.27	1,290.36
006 Albany - Schenectady - Troy, New York	38.00	349.70	5.56	1.33	798.17
007 Syracuse, N.Y.	28.09	202.56	3.65	3.87	508.70
008 Rochester,N.Y.	22.12	124.12	1.90	2.36	265.96
009 Buffalo, N.Y.	34.07	621.21	3.86	12.51	446.57
010 Erie, Pa.	7.23	189.68	1.06	3.89	116.69
011 Williamsport,Pa.	9.38	240.33	1.61	2.11	207.31
012 Binghampton, N.Y. - Pa.	9.98	182.36	.63	2.44	67.78
013 Wilkesbarre - Hazelton, Pa.	12.20	214.37	.75	1.95	86.68
014 New York, N.Y.	408.98	2,361.70	27.68	28.07	3,846.88
015 Philadelphia, Pa. - N.J.	157.28	915.51	15.03	17.88	2,088.59
016 Harrisburg,Pa.	37.76	835.68	4.58	3.70	615.77
017 Baltimore,Md.	46.14	490.53	4.13	10.27	541.84
018 Washington, D.C.- Md. - Va.	48.98	187.80	.64	.74	86.89
019 Staunton, Va.	4.80	316.94	.52	.55	54.74
020 Roanoke, Va.	18.56	1,519.85	3.37	2.10	372.02
021 Richmond, Va.	22.86	743.87	3.34	1.26	435.47
022 Norfolk - Portsmouth, Pa.	11.54	340.47	1.67	7.59	170.23
023 Raleigh, N.C.	15.66	782.80	2.29	1.58	281.81
024 Wilmington,N.C.	4.27	207.10	.69	.55	85.61
025 Greensboro - Winston-Salem - High Point, N.C.	14.46	1,972.79	2.45	3.14	197.95
026 Charlotte, N.C.	23.42	2,360.94	4.08	3.86	405.04
027 Ashville, S.C.	12.20	381.71	2.41	.77	324.01
028 Greenville,S.C.	9.26	213.54	1.11	.52	148.20
029 Columbia, S.C.	4.57	446.32	.59	.75	51.93
030 Florence, S.C.	11.96	252.24	2.44	.38	340.96
031 Charleston,S.C.	7.17	156.58	1.39	2.53	175.02
032 Augusta, Ga.	6.60	323.45	1.23	.59	155.80
033 Savannah, Ga.	14.30	304.40	2.81	1.18	388.54
034 Jacksonville, Florida	29.26	369.90	4.90	2.70	684.30
035 Orlando, Fla.	11.12	136.42	.32	1.27	37.35

Table 120 (con't)

OBE	AREA	PAPER	WOOD	RUBBER & PLASTIC	TEXTILE	OTHER
036	Miami, Fla.	25.45	385.19	1.37	6.82	144.24
037	Tampa - St. Petersburg, Fla.	17.48	194.71	.78	1.57	144.02
038	Tallahassee,Fla.	8.69	252.27	1.54	.45	206.68
039	Pensacola, Fla.	6.39	116.54	1.08	.38	148.50
040	Montgomery,Fla.	5.74	530.96	.84	1.85	76.91
041	Albany, Georgia	9.22	323.70	1.77	1.06	236.63
042	Macon, Georgia	6.69	401.21	1.29	.97	156.89
043	Columbus, Ga. - Alabama	3.44	239.47	.78	.67	22.16
044	Alanta, Georgia	44.46	775.65	5.64	11.47	711.41
045	Birmingham, Ga.	21.96	1,378.46	3.44	3.50	388.30
046	Memphis, Tenn. - Arkansas	22.28	1,067.67	2.77	1.48	325.06
047	Huntsville,Ala.	5.41	162.00	.63	.78	80.17
048	Chattanooga,Tenn.	9.41	388.28	1.34	.96	167.31
049	Nashville,Tenn.	16.93	732.59	.88	4.11	70.59
050	Knoxville, Tenn.	6.43	937.88	.94	1.49	64.73
051	Bristol, Va. - Tenn.	11.73	310.48	1.10	.54	140.59
052	Huntington, W. Va. - Ashland, Ky. - Ohio	6.03	369.00	.43	1.14	31.06
053	Lexington,Ky.	5.59	168.27	.35	.47	40.19
054	Louisville, Ky. - Indiana	20.17	602.39	1.82	2.51	219.87
055	Evansville,Ind.	6.82	802.13	1.11	1.43	99.07
056	Terre Haute,Ind.	5.13	38.90	.53	.23	76.92
057	Springfield,Ill.	7.22	51.96	.46	.49	68.87
058	Champaign - Urbana, Ill.	4.64	25.97	.09	.23	13.02
059	Lafayette - West Lafayette, Ind.	5.76	129.60	.16	.60	10.42
060	Indianaopolis, Indiana	29.33	336.03	2.95	11.08	329.61
061	Muncie, Ind.	9.64	124.73	1.12	3.34	135.59
062	Cincinnati, Ohio - Ky. - Ind.	46.54	482.24	5.43	7.01	734.02
063	Dayton, Ohio	34.03	125.62	2.86	4.88	382.45
064	Columbus, Ohio	29.53	235.05	3.20	4.19	437.41
065	Clarksburg,W.Va.	2.48	122.87	.25	.16	27.38
066	Pittsburg, Pa.	36.66	468.85	3.70	6.23	487.36
067	Youngstown - Warren, Ohio	4.92	157.39	.49	3.90	34.10
068	Cleveland,Ohio	88.26	555.74	8.01	22.10	972.12
069	Lima, Ohio	4.04	85.70	.53	2.90	51.28
070	Toledo, Ohio	17.33	340.67	2.19	6.25	258.36

Table 120 (con't)

OBE AREA		PAPER	WOOD	RUBBER & PLASTIC	TEXTILE	OTHER
071	Detroit, Mich.	62.42	401.03	6.77	77.57	405.20
072	Saginaw, Mich.	7.18	319.95	.90	5.65	71.04
073	Grand Rapids, Mich.	20.02	875.83	2.71	5.88	298.35
074	Lansing,Mich.	29.41	269.76	4.55	8.24	600.62
075	Fort Wayne,Ind.	10.46	151.30	1.01	4.59	108.63
076	South Bend,Ind.	19.62	539.64	3.02	5.61	368.32
077	Chicago, Ill.	216.38	2,070.48	18.38	16.06	2,543.10
078	Peoria, Ill.	7.07	77.66	.45	.29	68.85
079	Davenport - Moline, Iowa	9.65	187.70	1.07	.57	150.13
080	Cedar Rapids, Iowa	6.39	19.40	.42	.07	68.00
081	Dubuque, Iowa	2.56	71.24	.14	.30	30.41
082	Rockford, Ill.	8.21	176.47	.59	3.41	54.53
083	Madison, Wisc.	5.43	97.14	.17	.41	23.88
084	Milwaukee,Wisc.	50.59	334.94	3.46	9.29	442.80
085	Green Bay,Wisc.	54.65	621.66	9.91	1.27	1,412.08
086	Wausau, Wisc.	52.49	330.01	4.83	.76	686.92
087	Duluth, Minn. - Superior,Wisc.	16.44	187.70	2.80	.52	398.19
088	Eau Claire,Wisc.	6.29	90.60	.97	.25	139.29
089	La Crosse, Wisc.	2.68	84.20	.18	.36	22.16
090	Rochester,Minn.	2.90	51.74	.22	.13	36.92
091	Minneapolis - St. Paul,Minn.	66.84	421.54	5.68	2.84	828.27
092	Grand Forks,N.D.	.72	19.40	.01	.03	1.75
093	Minot, N.D.	.43	6.47	0	.01	.65
094	Great Falls,Mont.	1.25	38.80	.02	.06	1.30
095	Billings, Mont.	1.60	45.30	.06	.12	5.87
096	Bismarck, Ind.	.64	0	0	.01	.87
097	Fargo, N.D. - Moorhead, Minn.	2.06	19.46	.05	.15	6.95
098	Aberdeen, S.D.	.70	6.47	0	.02	1.52
099	Sioux Falls,S.D.	1.12	6.50	.01	.13	11.05
100	Rapid City, S.D.	1.02	38.86	.03	.17	.87
101	Scotts Bluff, Nebraska	.45	.03	0	.06	.87
102	Grand Island, Nebraska	1.80	6.57	.07	.20	13.24
103	Sioux City, Iowa - Nebr.	2.90	6.57	.05	.24	14.53
104	Fort Dodge,Iowa	2.08	12.96	.02	.13	8.88
105	Waterloo, Iowa	4.19	13.03	.18	.24	31.48
106	Des Moines,Iowa	11.78	77.79	.70	.49	101.02
107	Omaha, Nebraska - Iowa	10.32	97.23	.47	.64	78.17
108	Lincoln, Nebr.	3.82	51.90	.04	.37	6.93
109	Salinas, Kansas	1.48	6.57	.01	.18	1.73
110	Wichita, Kansas	6.49	69.44	.70	8.22	41.92

Table 120 (con't)

OBE AREA		PAPER	WOOD	RUBBER & PLASTIC	TEXTILE	OTHER
111	Kansas City, Mo. - Kansas	46.00	197.05	2.66	5.56	360.67
112	Columbia, Mo.	3.81	32.37	.05	.11	7.17
113	Quincy, Ill.	6.20	97.07	.78	.25	108.21
114	St. Louis, Mo. - Illinois	48.06	483.99	4.83	21.00	548.62
115	Paducah, Ky.	2.44	200.74	.23	.71	16.72
116	Springfield, Mo.	11.63	408.06	1.25	1.66	148.83
117	Little Rock - No. Little Rock, Ark.	12.32	1,080.57	2.15	1.38	116.68
118	Fort Smith, Okla.	4.09	426.88	.61	.68	58.01
119	Tulsa, Okla.	10.14	85.09	.53	1.93	69.29
120	Oklahoma City, Oklahoma	9.33	85.06	.30	1.85	31.48
121	Wichita Falls, Texas	1.11	45.37	.04	.23	1.95
122	Amarillo, Texas	2.10	25.90	.02	.10	2.38
123	Lubbock, Texas	.87	19.40	.01	.03	1.30
124	Odessa, Texas	1.16	6.47	.03	.02	5.22
125	Abilene, Texas	1.89	6.53	.01	.12	2.17
126	San Angelo, Texas	1.02	19.43	.01	.08	.87
127	Dallas, Texas	49.58	460.45	4.36	13.96	531.46
128	Waco, Texas	2.71	168.43	.25	.72	20.21
129	Austin, Texas	4.73	122.97	.08	.34	4.12
130	Tyler, Texas	6.41	569.36	1.03	1.18	105.81
131	Texarkana, Texas	4.13	401.05	.75	.69	78.44
132	Shreveport, La.	7.44	439.82	1.33	.68	159.50
133	Monroe, La.	14.40	401.14	2.94	.84	397.68
134	Greenville, Miss.	8.14	737.37	1.85	1.16	211.00
135	Jackson, Miss.	6.04	498.22	.98	1.10	108.19
136	Meridian, Miss.	12.19	840.74	2.72	1.12	333.79
137	Mobile, Ala.	26.49	499.56	5.29	3.48	722.77
138	New Orleans, La.	28.95	448.52	4.35	4.61	581.26
139	Lake Charles, La.	4.42	116.79	.57	.83	74.74
140	Beaumont - Port Arthur - Orange, Texas	6.04	233.23	.89	1.00	123.87
141	Houston, Texas	24.52	343.61	2.00	2.01	469.64
142	San Antonio, Texas	8.26	104.40	.43	1.77	37.35
143	Corpus Christi, Texas	1.95	19.53	.02	.26	2.82
144	Brownsville - Harlingen - San Benito, Texas	1.52	6.53	.07	.15	15.62
145	El Paso, Texas	4.49	39.02	.07	.46	8.47
146	Albuquerque, N.M.	4.26	90.57	.08	.18	8.03
147	Pueblo, Colo.	3.40	19.59	.06	.37	6.95
148	Denver, Colo.	20.22	156.27	.81	2.11	110.77
149	Grand Junction, Colo.	.85	51.74	.03	.07	1.08

Table 120 (con't)

OBE AREA		PAPER	WOOD	RUBBER & PLASTIC	TEXTILE	OTHER
150	Cheyenne, Wyo.	1.23	19.46	.02	.14	1.08
151	Salt Lake City, Utah	9.79	104.78	.40	2.42	39.95
152	Idaho Falls, Idaho	2.49	38.83	.06	.28	16.49
153	Butte, Montana	1.89	497.99	.47	.68	27.16
154	Spokane, Wash.	8.76	685.66	1.41	1.16	152.75
155	Seattle - Everett, Wash.	46.62	2,038.76	7.97	27.42	830.08
156	Yakima, Wash.	3.34	407.48	.66	.67	68.00
157	Portland, Ore.	42.92	2,188.31	7.63	7.05	923.97
158	Eugene, Ore.	5.97	2,295.92	1.83	3.12	72.79
159	Boise City,Idaho	2.03	252.43	.20	.74	11.07
160	Reno, Nevada	1.82	25.87	.02	.05	1.30
161	Las Vegas,Nevada	2.22	51.74	.03	.07	1.52
162	Phoenix, Arizona	13.33	163.31	.78	3.02	86.46
163	Tucson, Arizona	4.23	51.80	.36	.19	50.19
164	San Diego,Calif.	11.09	94.73	.51	7.26	19.97
165	Los Angeles - Long Beach, California	163.79	1,942.93	12.78	51.77	1,443.07
166	Fresno,Calif.	7.94	187.73	.29	.66	37.55
167	Stockton,Calif.	9.65	245.94	.86	.81	126.18
168	Sacramento,Calif.	14.04	252.43	.74	.80	97.53
169	Redding, Calif.	3.29	420.36	.72	.54	70.41
170	Eureka, Calif.	1.51	562.63	.51	.71	27.16
171	San Francisco - Oakland, Calif.	87.58	697.51	6.29	10.71	860.79
172	Anchorage,Alas.	6.96	187.57	1.29	.30	175.80
173	Honolulu,Hawaii	8.62	78.27	.36	1.39	58.17

APPENDIX E

NATIONAL DISTRIBUTION OF WASTE GENERATION ACTIVITIES, BY CENSUS REGIONS

Appendix E shows the geographical distribution of major sources of CSW in the U.S. These sources are broadly divided into agricultural and industrial categories. The other major source of CSW--municipal-type waste--is distributed roughly in proportion to population. CSW projections and distributions for commercial, institutional, household wastes, and sewage sludge, by SMSA, are given in Appendix B.

The distribution of waste generating activity was done under subcontract by Economic Associates, Inc. The agricultural and industrial activities to be studied were those which a preliminary analysis indicated would be important from a CSW point of view--either in quantity of waste generated or due to peculiarities of concentration. This list was updated and revised as further study indicated increased importance of sectors not listed, or decreased importance of those which were listed.

Table 121 lists those commodities and industries which were finally decided upon as being of CSW-generating significance. The commodities or industries listed in the table have been assigned index numbers as given in the table. The index numbers have been assigned as follows: first digit, task area of subcontract (1); second four digits, SIC number; remaining digit(s), table identification number. The complete set of regionalization data, which may be viewed at the Solid Waste Division of the National Environmental Research Center, 5555 Ridge Avenue, Cincinnati, Ohio, is organized according to these index numbers.

CRITERIA FOR DEVELOPING GEOGRAPHICAL DISTRIBUTIONS

The units which were chosen to be the determining criteria as regards geographical distribution varied depending on the commodity or industry. Distribution of agricultural activity was based on the physical quantity of the commodity produced. Cattle slaughtered were based on both live weight and number of head. Geographical distribution of industrial activity was based on value added, value of production, or value of shipments. The precise output unit for each sector analyzed is given in Table 122. Each distribution accounts for at least 90% of the output from that sector, as measured in the appropriate units.

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TABLE 121

Regionalization Projections

Table No.	Index No.[1]	Commodity or Industry	
124	1-0112	Cotton	Projections and Rationale
125	1-0113-1	Corn	Projections and Rationale
126	1-0113-2	Oats	Projections and Rationale
127	1-0113-3	Barley	Projections and Rationale
128	1-0113-4	Sorghums	Projections and Rationale
129	1-0113-5	Wheat	Projections and Rationale
130	1-0113-6	Rye	Projections and Rationale
131	1-0113-7	Rice	Projections and Rationale
132	1-0113-8	Soybeans	Projections and Rationale
133	1-0113-9	Dry Beans	Projections and Rationale
134	1-0119-1	Alfalfa and Clover Seed	Projections and Rationale
135	1-0119-2	Flaxseed	Projections and Rationale
136	1-0119-3	Peanuts	Projections and Rationale
137	1-0119-4	Irish Potatoes	Projections and Rationale
138	1-0119-5	Sugar Beets	Projections and Rationale
139	1-0729	Cattle Feedlots and Fed Cattle Marketed	Projections and Rationale
140	1-2011-1-1	Cattle Slaughter	Projections and Rationale
141	1-2011-1-2	Cattle Slaughter Plants	Historical
142	1-2011-2-1	Calf Slaughter	Projections and Rationale
143	1-2011-2-2	Calf Slaughter Plants	Historical
144	1-2011-3-1	Sheep and Lamb Slaughter	Projections and Rationale
145	1-2011-3-2	Sheep and Lamb Slaughter Plants	Historical
146	1-2011-4-1	Hog Slaughter	Projections and Rationale
147	1-2011-4-2	Hog Slaughter Plants	Historical
148	1-2011-5	Meat Packing Plants	Projections and Rationale
149	1-2011-6	Manure Generated by Livestock	Projections and Rationale
150	1-2011-7	Manure Generated by Poultry	Projections and Rationale
151	1-2011-8	Manure Generated by Livestock and Poultry	Summary Table
152	1-2031	Canned and Cured Fish and Seafood	Projections and Rationale
153	1-2033	Canned Fruits, Vegetables, Preserves, Jams and Jellies	Projections and Rationale

Table 121 (con't)

Table No.	Index No. 1/	Commodity or Industry	
154	1-2036	Fresh or Frozen Packaged Fish	Projections and Rationale
155	1-2037	Frozen Fruits, Juices, and Vegetables	Projections and Rationale
156	1-2041	Flour and Other Grain Mill Products	Projections and Rationale
157	1-2200	Textile Mill Products	Projections and Rationale
158	1-2231	Yarn and Weaving Mills, Wool	Projections and Rationale
159	1-2300	Apparel and Other Textile Products	Projections and Rationale
160	1-2400	Wood Products incl. Containers and Furniture	Projections and Rationale
161	1-2420	Sawmills and Planing Mills	Projections and Rationale
162	1-2611	Pulp Mills	Projections and Rationale
163	1-2621	Paper Mills, except Building Paper Mills	Projections and Rationale
164	1-3011	Rubber Tires and Tubes	Projections and Rationale
165	1-3069	Fabricated Rubber Products, NEC	Projections and Rationale
166	1-3111	Leather Tanning and Finishing	Projections and Rationale

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1/ Index numbers have been assigned as follows: first digit, task area of subcontract; second four digits, SIC number; remaining digit(s), table identification number.

TABLE 122

OUTPUTS: UNITS ON WHICH GEOGRAPHICAL DISTRIBUTION ARE BASED

SIC No.	Industry Name	Output Unit
2011	Meatpacking	Value shipments
2031	Canned and cured fish and seafood	Value production
2033	Canned fruits, vegetables, etc.	Value production
2036	Fresh or frozen packaged fish	Value production
2037	Frozen Fruits, juices and vegetables	Value production
2041	Flour and other grain mill products	Value shipments
2200	Textile mill products	Value shipments
2231	Yarn and weaving mills-wool	Value added
2300	Apparel and other textile products	Value added
2400	Wood products, incl. containers and furniture	Value added
2420	Sawmills and planing mills	Value shipments
2611	Pulp mills	Value shipments
2621	Paper mills, except building paper	Value shipments
3069	Fabricated rubber products	Value shipments
3111	Leather tanning and finishing	Value shipments
5411	Supermarkets	Number

The geographic breakdown began by determining the distribution of the total national output among four Census Regions: Northeast, North Central, West, and South. Whenever a region contained more than 20% of the total national output, the region was broken into census subregions and the distribution among those subregions was determined. If any of those subregions contained more than 20% of total national output, the distribution among states within that subregion was determined. Within states, should any state at the level of OBE area account for more than 20% of the total national output, the distribution was determined according to the following rules:

a. If the state contains one or more entire OBE areas: Sum (as available or estimate) county data to determine each OBE area, then subtract such OBE area from the state total. Should the remainder of a state still represent 20% or more of total national output, follow b. below.

b. If the state contains no OBE areas entirely within its borders:

(1) Sum county data for all OBE areas which include part of the state and part of one or more other states within the same census subregion. Adjust census subregions breakdown and redistribute, by OBE area so calculated, with the remainders of the states included. For example, if North Dakota exceeded 20%, the breakdown could be:

West North Central

- Iowa
- Missouri
- South Dakota
- Nebraska
- Kansas
- OBE 92
- OBE 97
- North Dakota
- Minnesota, remainder

(2) Should an OBE account for 20% or more of total national output, it may be possible to break out the OBE total further by estimating for Standard Metropolitan Statistical Areas (SMSA's) contained within the OBE area. This would follow the principles outlined above.

The historical distribution and projected distribution are usually given in terms of "% of total U.S. output", except where noted. The rationale for a changed distribution in the projections is given on the page following the specific regionalization table.

The regionalization in this Appendix is distribution of waste generators (sources of CSW), rather than wasteloads explicitly. Calculation of the absolute quantities of waste in each region from each source can be done by locating the appropriate commodity, SIC 4, 3, or 2 digit sector total wasteload (base year or projected) in Tables 91 and 99, and distributing it according to the concen--ration of that source given here in Appendix E. In Table 99, however, individual commodities cease to appear (unless they constitute the sole output of a larger sector), and projected output must therefore be estimated from the growth rate of the smallest economic sector in which it is included.

Table 123 indicates expected shiftsin percentage distribution of National Production of Selected agricultural commodities among the four Census geographic Regions between 1969 and 1990.

NOTE: Because of space limitations, only those regional distribution tables related to important problem wastes (from a quantity or non-uniform national distribution viewpoint) are included in this appendix. A complete set may be viewed at the Solid Waste Division of the National Environmental Research center, 5555 Ridge Avenue, Cincinnati, Ohio.

TABLE NO.	INDEX NO.	DESCRIBES DISTRIBUTION OF:
139	1-0729	Cattle feedlots
140	1-2011-1-1	Commercial slaughter - cattle
159	1-2300	Apparel and other textile products
160	1-2400	Wood products, including containers and furniture
161	1-2420	Sawmills and planing mills
162	1-2611	Pulp mills

CATTLE FEEDLOTS (INDEX NO. 1-0729)

In 1970, over 70 percent of the 35.1 million head of cattle slaughtered commercially were marketed from feedlots producing over 15 million pounds of beef. By 1980, the U.S. Department of Agriculture estimates that 29.2 billion pounds of beef will have to be produced, requiring a slaughter of beef cattle of approximately 47 million head.

TABLE 123

Grains & Selected Agricultural Products

Shift in Percentage Distribution of National Production

1969 - 1990

	Census Geographic Region			
Commodity	Northeast	No. Central	South	West
Cotton.........	*	*	-	+
Corn...........	*	+	-	*
Oats...........	-	+	-	*
Barley.........	*	-	+	+
Sorghums.......	*	*	-	+
Wheat..........	-	-	+	+
Rye............	-	+	+	-
Rice...........	*	*	+	-
Soybeans.......	*	-	+	*
Dry Beans......	*	+	*	-
Alfalfa........	*	-	+	+
Flaxseed.......	*	+	-	-
Peanuts........	*	*	*	+
Irish Potatoes.	+	-	-	+
Sugar Beets....	*	*	+	-

Note: *=little or no change

- = decreasing percentage

+ = increasing percentage

An ever increasing proportion of these cattle will be marketed from feedlots. Farmer feeders, operators of lots with less than 1,000 head capacity, are primarily located in the older, established feeding areas of the East and West North Central Region. The commercial cattle feedlots generally dominate output in the newer cattle feeding areas of the West South Central Division and the West Region. The commercial feedlots, though fewer in number, are expected in the future to dominate the industry.

The projections for 1980 and 1990 reflect the anticipated industry trend toward fewer, larger lots located in or near major surplus grain producing areas, with readily available supplies of feeder cattle and adequate slaughter facilities nearby.

In the future, it is expected that the strongest competitive feedlot complexes in the industry will be located in the West North Central States of Kansas, Nebraska, Iowa and Missouri, in the West South Central States of Oklahoma and Texas, and in the Mountain States of Colorado, New Mexico, and Arizona. These nine states, which in 1970 accounted for 71 percent of cattle marketing from the 23 major feeding states shown in Table 139, are projected to account for 85 percent of marketings in 1980 and 93 percent in 1990.

COMMERCIAL CATTLE SLAUGHTER (Index No. 1-2011-1-1)

Commercial cattle slaughter has accounted for over 60 percent of the total livestock liveweight slaughter in recent years and is expected to increase its share of the total in the future. As per capita personal incomes continue to rise consumers are expected further to indulge their preference for beef, resulting in stable or declining demands for veal, pork, and lamb and mutton. In 1970, commercial cattle slaughter amounted to 36 billion pounds liveweight, which produced some 21 billion pounds of beef. Thus, the waste potential of cattle slaughter was about 15 billion pounds or over 40 percent of the total liveweight slaughter. While the ratio of beef produced to liveweight slaughtered has been slowly improving, the total poundage of waste potential may be expected to continue to increase as more animals are slaughtered each year.

The geographical distribution of commercial cattle slaughter has been gradually shifting in line with shifts in commercial cattle feeding and this parallel shift is expected to continue in the future. The North Central Region is projected to retain over half of the total cattle slaughter, both in terms of liveweight and number of head slaughtered in 1980 and 1990, but will probably decline slightly below the 1970 level. Within the region the share of the East North Central Division is projected to fall off about one-half between 1970 and 1990 while the West North Central Region increases, reflecting greater concentration of slaughtering activity in Nebraska and in the Remainder states, chiefly Kansas.

TABLE 139
(Index No. I-0729)

SIC 0729 -- Number of Cattle Feedlots and Fed Cattle Marketed, 23 Major Feeding States1/
(Percent distribution)

Geographical area	1965		1967		1970		1980		1990	
	Lots	Cattle	Lots	Cattle	Lots	Cattle	Lots	Cattle	Lots	Cattle
23 Feeding States1/	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Northeast (Pa.)	2.8	0.6	2.9	0.6	3.3	0.5	5.0	0.3	6.6	0.2
North Central	93.4	62.9	93.6	64.2	93.6	59.5	92.1	54.6	90.4	47.3
East North Central	30.4	14.5	30.4	12.7	31.2	10.4	32.2	5.2	32.7	2.3
Illinois	13.4	7.3	13.1	6.1	13.0	4.7	11.4	1.9	10.2	0.6
Remainder	17.0	7.2	17.3	6.6	18.2	5.7	20.8	3.3	22.5	1.7
West North Central	63.0	48.4	63.2	51.5	62.4	49.1	59.9	49.4	57.7	45.0
Iowa	21.8	18.4	22.4	19.4	22.8	18.4	24.4	18.0	25.2	15.7
Nebraska	10.6	13.6	10.8	14.7	10.2	14.3	8.6	14.2	7.3	12.7
Kansas	6.2	4.8	5.8	6.3	4.9	7.6	2.5	10.6	1.4	11.7
Minnesota	9.9	3.8	9.7	4.2	9.9	3.5	9.8	2.6	9.5	1.7
Missouri	8.3	3.7	8.7	3.3	8.7	2.7	9.2	3.1	9.4	2.9
Remainder	6.2	4.1	5.8	3.6	6.0	2.6	5.4	0.9	4.9	0.3
South (West So. Central)	1.6	7.8	1.5	9.9	1.3	14.8	1.3	20.9	1.5	24.0
Texas	0.8	6.1	0.8	7.9	0.9	12.6	1.2	17.6	1.5	19.4
Oklahoma	0.8	1.7	0.7	2.0	0.4	2.2	0.1	3.3	--	4.6
West	2.2	28.7	2.0	25.3	1.8	25.2	1.6	24.2	1.5	28.5
Mountain	1.4	13.3	1.3	13.1	1.2	15.2	1.2	20.0	1.3	26.9
Colorado	0.6	6.4	0.6	6.4	0.6	7.7	0.6	10.8	0.6	13.7
Arizona	--	3.6	--	3.1	--	3.5	--	3.3	--	2.9
Idaho	0.4	1.5	0.4	1.7	0.3	1.7	0.1	1.4	0.1	1.1
New Mexico	0.1	1.0	0.1	1.1	--	1.6	--	4.0	--	8.9
Montana	0.3	0.8	0.2	0.8	0.3	0.7	0.5	0.5	0.6	0.3
Pacific	0.8	15.4	0.7	12.2	0.6	10.0	0.4	4.2	0.2	1.6
California	0.3	12.7	0.3	9.8	0.2	7.9	0.1	3.0	--	1.0
Remainder	0.5	2.7	0.4	2.4	0.4	2.1	0.3	1.2	0.2	0.6

1/ These states accounted for an estimated 94% of the U. S. total fed cattle marketed in 1965, 95% in 1967, and 96% in 1970.

Source: To 1970, U. S. Department of Agriculture; 1980 and 1990, ECASSO.
Economic Associates, Inc.

TABLE 140
(Index No. 1-2011-1-1)

SIC 2011 (Part) -- Commercial Slaughter - Cattle

(Percent distribution)

Geographical area	1965		1967		1970		1980		1990	
	Live wt. Basis	No. Head	Live wt. Basis	No. Head	Live wt. Basis	No. Head	Live wt. Basis	No. Head	Live wt. Basis	No. Head
United States	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Northeast	6.8	6.1	5.6	5.1	5.1	4.6	3.3	2.8	1.7	1.3
North Central	55.3	53.8	57.5	55.8	56.4	54.9	55.3	54.0	54.5	53.3
East North Central	17.6	17.3	15.7	15.4	14.0	13.7	9.5	9.3	5.8	5.6
West North Central	37.7	36.5	41.8	40.4	42.4	41.2	45.8	44.7	48.7	47.7
Nebraska	9.2	8.9	10.9	10.5	12.8	12.4	14.8	14.4	16.5	16.2
Iowa	12.8	12.3	12.9	12.5	12.7	12.3	12.5	12.1	12.2	11.9
Remainder	15.7	15.3	18.0	17.4	16.9	16.5	18.5	18.2	20.0	19.6
South	17.0	19.4	16.2	18.5	16.9	19.0	13.1	20.0	19.1	20.8
West	20.9	20.7	20.7	20.6	21.6	21.5	23.3	23.2	24.7	24.6
Mountain	8.5	8.5	8.8	8.8	10.8	10.6	16.2	16.0	20.7	20.5
Pacific	12.4	12.2	11.9	11.8	10.8	10.9	7.1	7.2	4.0	4.1

Source: To 1970, U. S. Department of Agriculture; 1980 and 1990, ECASSO Economic Associates, Inc.

The West Region, next in importance in 1970 with over one-fifth of the total cattle slaughter, is expected to increase its share over 1970 by about three percentage points to almost 25 percent by 1990. This will result from almost a two-fold increase in the share of the Mountain states.

The above trends will offset the expected decline in liveweight slaughter in the Northeast Region and in the Pacific Division.

Although the liveweight slaughter in 1990 in the South will represent about the same share as in 1970, a slight gain is expected in the share of the head of cattle slaughtered in 1990, largely because of increased activity in Oklahoma and Texas.

APPAREL AND OTHER TEXTILE PRODUCTS (Index No. 1-2300)

The apparel industry is one of the country's largest industries. Value added expenditure rose from $6.0 billion in 1958 to $10.1 billion in 1967. Of this total in 1967, nearly 32 percent was from the production of women and misses outerwear and 22 percent from men's and boys' furnishings. The industry is highly labor intensive and is sensitive also to foreign competition in countries where labor costs are below American wage standards.

A steady decline in the importance of the Northeast Region has been underway for some time. The percentage share of value added expenditures coming from the Northeast fell from 61 percent in 1958 to 51 percent in 1967, and is projected to drop to 35 percent by 1990. The exodus of the industry from the Northeast, in particular from New York, has been largely a result of high labor costs. Because the industry characteristically has a high proportion of small operations, many plants are easily relocated. In New York (primarily in OBE 14) in 1967 there were some 6,580 plants with 20 or fewer employees, a drop of about 27 percent below the almost 9,000 small plants operating in 1958. Further declines are anticipated, and the share of New York is expected to fall to about 17.5 percent by 1990. The remainder of the Mid Atlantic Division, however, will experience a much smaller decline because many of the plants moving out of New York City are relocating in New Jersey and Pennsylvania whenever feasible.

The South Region has been the major beneficiary of the exodus from the Northeast, particularly the South Atlantic Division, primarily the states of Florida, Georgia and the Carolinas. Since 1958, the share of the South in total U.S. activity rose from 20 percent to 30 percent in 1967. This share is expected to continue rising to about 45 percent in 1990. The apparel industry in the South has had significantly lower labor costs, weaker unions, less expensive land and lower taxes. However, the South is now attracting many other industries, and the apparel industry will have to compete for labor and face rising costs of operations. Therefore, the rate of expansion will tend to level off between 1980 and 1990.

TABLE 159
(Index No. I-2300)

SIC 2300 - Apparel and Other Textile Products
(Percent distribution)[1]

Geographical area	1958	1963	1967	1980	1990
United States	100.0	100.0	100.0	100.0	100.0
Northeast Region	60.6	55.0	50.6	40.0	35.0
New England	7.2	6.2	5.7	4.0	2.5
Mid-Atlantic	53.4	48.8	44.9	36.0	32.5
New York	36.4	31.5	28.6	21.0	17.5
OBE 14-New York	33.2E	28.7E	19.1E	13.0	9.5
NY. Remainder	3.2E	2.8E	9.5E	8.0	8.0
Remainder	17.0	17.3	16.3	15.0	15.0
North Central Region	12.7	12.8	12.6	13.0	13.0
South Region	20.1	25.4	29.9	40.0	45.0
South Atlantic	10.7	13.2	15.2	20.0	22.0
East South Central	6.0	8.0	9.7	13.0	15.0
West South Central	3.4	4.2	5.0	7.0	8.0
West Region	6.6	6.8	6.9	7.0	7.0

E - Estimated by ECASSO

[1] Computed from data on value added in U.S. Department of Commerce, Bureau of Census, Census of Manufactures for years shown.

The North Central and West Regions are expected to maintain their share, holding steady in 1990 at about 13 percent and 7 percent respectively. Each region's activity has been generated substantially by the large metropolitan centers located within them. In 1967, two-thirds of the activity in the North Central Division was in men's and boys' suits and furnishings, womens' and misses outerwear, and automotive and apparel trimmings. More than three-quarters of the activity in the West was mens' and boys' furnishings, womens' and misses outerwear and house furnishings.

WOOD PRODUCTS, INCLUDING CONTAINERS AND FURNITURE (Index No. 1-2400)

This industry, as here defined, covers SIC industry groups 24 and 25 except for metal products. It, therefore, includes millwork products, plywood, veneer and prefabricated buildings, wooden containers, wood preserving, wood household furniture, and wood partitions, shelving and office and store fixtures.

In terms of value added expenditures, the industry grew 75 percent between 1958 and 1967. In 1967, SIC 243, millwork products, and SIC 2511, wood household furniture (except upholstered), accounted for 53 percent of the total value added. Continued growth in this composite industry, as defined, can be expected because its activity is closely related to new household formation which will continue strong through 1990, particularly in the South and West.

The veneer and plywood, wood preserving, and wooden containers industries are usually located near timber resources. However, the millwork plants, prefab buildings and furniture plants are more widely dispersed throughout the country.

The Northeast Region is projected to decline from 17 percent in 1967 to about 13 percent in 1990. Between 1958 and 1967, it remained steady only in its national share of millwork products and office and store fixtures.

The North Central Region also is projected to decline from 24.6 percent in 1967 to 21 percent in 1990. The Region has accounted for 35 percent of the nation's millwork and 44 percent of its prefab housing. It is expected that Indiana, which has been the third largest producing center for wood household furniture, and the Grand Rapids, Michigan area will maintain their relative standing.

The projected increase of the South's share from about 37 percent in 1967 to 42 percent in 1990 is based partly on the assumption that there will be a continued growth in plywood and particle board operations in the South Central states. Between 1962 and 1967, 24 of 34 new southern pine plywood plants were built in the South Central States. New plants are planned in Arkansas, Texas, Louisiana, and Oklahoma,largelybecause of anticipated construction

Table 160
(Index No. 1-2400)
SIC 2400 -- Wood Products Including Containers and Furniture[1/]

(Percent distribution)

Geographic area	1958[2/]	1963	1967	1980	1990
United States	100.0	100.0	100.0	100.0	100.0
Northeast Region	20.5	18.0	17.0	14.0	13.0
North Central Region	26.5	24.1	24.6	23.0	21.0
East North Central	21.2	19.7	20.1	19.5	18.5
Indiana	5.4	5.3	5.2	5.5	5.5
Michigan	4.0	4.0	4.5	4.5	4.5
Remainder	11.8	10.4	10.4	9.5	8.5
West North Central	5.3	4.5	4.4	3.5	2.5
South Region	30.7	34.0	36.9	40.0	42.0
South Atlantic	18.2	20.2	21.5	23.0	23.5
Virginia	3.9	4.7	4.8	5.5	5.5
North Carolina	7.8	9.2	10.4	11.5	12.5
Remainder	6.5	6.3	6.3	6.0	5.5
East South Central	6.7	8.1	8.8	9.5	10.0
West South Central	5.8	5.7	6.6	7.5	8.5
West Region	22.5	23.9	21.5	23.0	24.0
Mountain	1.4	1.4	1.6	2.0	2.0
Pacific	21.1	22.5	19.9	20.0	21.0
Oregon	7.1	8.1	7.1	6.0	5.0
California	10.3	11.0	9.5	11.0	12.0
Remainder	3.7	3.4	3.3	4.0	5.0

[1/] Computed from data on value added in U. S. Department of Commerce, Bureau of Census, Census of Manufactures, for years shown. Includes SIC 243, 244, 249, 2511, 2512, 2515, 2521, 2531, and 2541.

[2/] 1958 totals for SIC 2541 were not given in the 1958 Census. Estimates were made and based on the percent share 2541 was of 254 in the 1963 Census.

and furniture requirements. In view of strong demand, it is expected that North Carolina and Virginia, now the largest wooden household furniture producing states, will increase their share of overall output.

A slight rise in the share of the Mountain and Pacific states is projected. Population growth in the West has been, and is expected to be, most concentrated in California which will remain a strong product demand center. At the same time, Oregon, Washington, and California continue to be the leading producers of the most diversified plywood product mix. Also Oregon has been the leading producer of particleboard. This leadership, however, may shift to Washington which will tend to increase the share of the Remainder portion of the Pacific division.

SAWMILLS AND PLANING MILLS (Index No. 1-2420)

Of the three 4-digit industry groups (2421, 2426, and 2429) covered by Table 161, SIC 2421, Sawmills and Planing Mills, General, accounted for more than four-fifths of total value of shipments for Industry Group 242 in 1967. SIC 2421 includes establishments primarily engaged in sawing rough lumber and timber from logs and bolts, and producing boxlumber and cut stock. It also includes planing mills combined with sawmills, and separately operated planing mills which were engaged primarily in producing surfaced and patterned lumber. Further, it includes establishments primarily engaged in sawing railroad ties, tobacco hogshead stock and lath. Logging camps were combined with sawmills when not separately reported.

Industry 2426, Hardwood Dimension and Flooring Mills, includes establishments primarily engaged in manufacturing hardwood dimension lumber and hardwood flooring. Industry 2429, Special Product Sawmills, includes mills primarily engaged in producing excelsior, wood shingles, cooperage stock, and special sawn products, not elsewhere classified.

During the period 1958-1966 the lumber industry grew more slowly than did manufacturing as a whole. In the eight year period, value added increased only 49 percent as compared with 78 percent. For the largest group, SIC Industry 2421, however, the U.S. Department of Commerce has projected an annual growth rate of 4.3 percent in the value of shipments for the decade 1970-80.

Output of the lumber industry has been traditionally, and will continue to be, heavily influenced by residential construction where lumber use per housing unit has been affected by increased competition from other building materials such as brick, concrete block, asbestos, aluminum siding, and glass. Anticipated future construction needs, however, will still require a greater volume of lumber despite new technologies in building. Overall, however,

TABLE 161
(Index No. 1-2420)

SIC 2421, 2426, and 2429 -- Sawmills and Planing Mills
(Percent distribution[1])

Geographical area	1958	1963	1967	1980	1990
United States	100.0	100.0	100.0	100.0	100.0
Northeast Region	5.3	5.3	5.8	6.9	7.7
North Central Region	5.5	5.7	6.2	7.4	8.4
South Region	37.3	37.5	37.9	38.8	39.1
South Atlantic	17.1	15.6	15.9	15.0	14.0
East South Central	10.7	11.4	12.2	14.7	16.7
West South Central	9.5	10.4	9.8	9.1	8.4
West Region	51.9	51.5	50.1	46.9	44.8
Mountain	8.5	9.3	9.8	11.7	13.1
Pacific	43.4	42.1	40.3	35.2	31.7
Oregon	17.8	17.1	16.3	13.8	11.9
California	14.7	14.4	13.0	10.1	8.2
Washington	10.4	10.3	10.3	10.0	9.6
Remainder	0.5	0.3	0.7	1.3	2.0

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[1] Computed from data on value of shipments in U. S. Department of Commerce, Bureau of the Census, Census of Manufactures for the years shown.

pressures created by an increasing awareness of the conservation of natural resources will tend to reduce the utilization of lumber and lumber products.

In the past, proximity to the supply of timber has largely determined the location of the sawmills, plywood and other industry mills. This consideration will continue to be effective in the future. However, it is expected that industry activities in 1980 and 1990 will shift moderately from the Pacific Region. On the basis of historical trends, however, the concentration of industry activity in or near the forests of the Pacific Division (primarily Washington, Oregon, and California) will decline heavily as lumbering increases in the Mountain Division and the other regions. Nevertheless, the West Region will hold on to nearly 45 percent of the national activity in 1990 compared with 50 percent in 1967. There will be a significant increase in the Northeast and North Central Regions, each accounting for about 6 percent of the national total, will grow to about 8 percent of the total by 1990.

PULP MILLS (Index No. 1-2611

Industry 2611 includes establishments in the United States which primarily are engaged in manufacturing pulp principally from wood, or from other materials such as rags, linters, waste papers, and straw. It also includes logging camps operated by pulp mills when they cannot be separately reported. SIC 2611, however, does not include integrated pulp and paper mills.

The geographical distribution of the industry, to an even greater extent than that of paper mills, has traditionally been determined by proximity to sources of raw materials (principally forested areas) and an adequate water supply, rather than proximity to consuming markets. This situation is gradually changing. Mills can transport raw materials and new closed, recycling processes are being developed which require a less abundant supply of water.

In the future, however, pulp mills will continue to be located primarily in the South and West Regions. In the South Region, the highest value of shipments originates in the South Atlantic states of South Carolina, Georgia, and Florida. Mill activity in the East South Central Division is scattered chiefly in Tennessee, Alabama, and Mississippi. Pulp mills in the West Region are concentrated in the state of Washington, particularly in OBE 155. About 17 percent of the nation's shipments in 1967 was spread among Oregon, California, Alaska, and Idaho.

The South Region is expected to account for almost half of the value of shipments from non-integrated pulp mills in 1980 and 1990. (The slight increase shown is based on an expected increase in the use of

Table 162
(Index No. 1-2611)
SIC 2611 -- Pulp Mills
(Percent distribution)[1]

Geographical area	1958	1963	1967	1980	1990
United States	100.0	100.0	100.0	100.0	100.0
Northeast Region	16.5	6.7	10.4	7.5	5.3
Northcentral Region	3.7	2.5	2.6	2.3	2.0
South Region[2]	45.8[3]	50.7[3]	44.9	47.6	49.7
South Atlantic	na	na	28.7	29.9	30.9
Georgia	na	na	E13.1	13.5	13.9
Florida	na	na	E 9.1	9.7	10.2
South Carolina	na	na	E 6.5	6.7	6.8
East South Central	na	na	16.2	17.7	18.8
West Region[4]	34.0	40.1	42.1	42.6	43.0
Washington	28.2	26.8	25.5	23.5	22.0
OBE 155	na	na	E21.3	19.6	18.4
Remainder	na	na	E 4.2	3.9	3.6
Remainder	5.8	13.3	16.6	19.1	21.0

E - Estimated by ECASSO
na - Not available

[1] Computed from data on value of shipments in U S. Department of Commerce, Bureau of the Census, Census of Manufactures for years shown.

[2] No pulpmills reported in West South Central Division.

[3] More detailed breakdown not available.

[4] Breakdown not available for Mountain and Pacific Divisions.

byproduct wood chips in pulp making.) The east South Central Division is projected to grow at a slightly faster rate than the South Atlantic Division as forest land there and in the West South Central states of Arkansas and Louisiana is increasingly utilized.

The West Region will continue to ship over 40 percent of the national total, although experiencing a decline as the South assumes greater importance. Moreover, the Northeast and North Central Regions both will show a declining share of the nation. In the latter Region activity may increasingly be confined to the manufacturing of specialty pulps from the hardwood resources located there and the processing of the small amount of pulpwood which is imported, chiefly from Canada.

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